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OPTIMIZING WAREHOUSE LOGISTICS OPERATIONS THROUGH SITE SELECTION MODELS: ISTANBUL, TURKEY

by

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March 2003

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13. ABSTRACT

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I. INTRODUCTION

A. BACKGROUND

Warehousing has been a part of civilization for thousands of years. Warehousing is the function of storing goods between the time they are produced and the time they are needed [Ref. 1]. In practice, goods are sent to storage points close to the market and are issued to consumers from these points easily and in small amounts when needed. Although warehousing was initially a means of storing foodstuffs, today it is a broad and complex issue [Ref. 3, 4]. For example, there are more than 300,000 large warehouses and 2.5 million employees in the United States alone. The cost of American warehousing is more than 5 percent of the gross national product [Ref. 2].

A warehouse is a distribution factory. The warehousing functions far exceed the mere provision of a building to protect the stored goods from the elements. Furthermore, any warehouse is a complex, constantly evolving center, which must be able to cope with a myriad of expansions and expectations and must do so cost effectively. Adequate space, customer service, favorable traffic connections with suppliers and key markets, easy freeway access, proximity to trains and airports and a qualified work force–these are only some of the factors that a warehousing study must evaluate [Ref. 5].

In order to succeed in certain demand areas, organizations must have a warehouse presence [Ref. 11]. Naturally, capital investment, operating expenses, and customer service are all affected by decisions regarding site and structure [Ref. 5]. As a result, storage should be considered as a resource. Investments in storage facilities should be identified through an initial study and must be followed by a feasibility analysis. The location of warehousing must be studied carefully prior to undertaking the other complex issues inherent in a storage study [Ref. 5].

Before a site is selected, all management levels and business entities must participate in the analysis. Unfortunately, warehouse location projects frequently are understaffed, under-funded, and fail to consider fully the entire distribution network's current capabilities and future requirements. The process of selecting a site requires a

clear understanding of the underlying strategy to be developed and must communicate this research to all the stakeholders involved. Obtaining buy-in from all levels and departments of the organization to ensure a successful analysis and decision is necessary [Ref. 11].

Warehouse design begins with determining the best warehouse location. The design process also includes the layout, storage methods, equipment and automated systems, source and nature of the supplies, zones, and order receiving methods [Ref. 4, 6].

Clearly, owing to its complexity, site selection is one of the most challenging and important responsibilities of logistics managers. The task of site selection literally involves art as well as science. Site selection has a major impact on logistics costs and operational efficiency. A warehouse poorly located can deal a costly and even a mortal blow to the life of an organization heavily involved in physical distribution [Ref. 2, 3, 9]. The site selection process begins at the highest strategic (macro) level and descends until a specific real estate parcel is chosen [Ref. 9]. Then the site selection process usually involves weighing priorities, determining the critical features, and eliminating inadequate sites. Since every location has advantages and disadvantages, the final selection of a site is likely to involve some compromises [Ref. 2, 3].

The first step to consider is asking why one is seeking a new warehouse site. The following are four common reasons [Ref. 2, 3]:

- Relocating to an existing warehouse operation is necessary.
- Inventory must be moved to a new location due to expanding responsibilities.
- Additional warehouse space is needed to accommodate a growing inventory.
- Contingency planning requires decentralizing existing warehousing.

Depending on which of the above reasons is the primary motive for seeking a new warehouse, the site search can assume many different forms.

B. PURPOSE

The purpose of this research is to find the best logistics supply center location for the Turkish Navy in Istanbul so that it can perform its mission better and can capitalize on the latest technological developments.

Owing to age, technological obsoleteness, and expanding population and urbanization, many difficulties with the existing facilities have ensued. The current Logistics Command is at least 50 years old and due to the 1999 earthquake, significant tactical and strategic level changes have been needed in the logistics system of the Turkish Navy. Therefore, the current supply system and relocation reviews are gaining importance and becoming an urgent requirement for the Navy's future capabilities.

Coupled with the location reviews of the supply center in Istanbul, this research must also consider the most current IT and other relevant logistics innovations.

The Turkish Navy's dedication and commitment to this relocation is crucial. Additionally, since the site selection for warehouses is one of the most important decisions the leadership will make in the short term, the site selection project managers must employ the necessary experts and provide other necessary resources. Consequently, this research will employ two different site selection models to pinpoint a better location for the current logistics supply center in Istanbul.

C. THE RESEARCH CASE AND METHODOLOGY

This study will provide a background on the Turkish Navy's current logistics supply center and warehouses in Istanbul, a general history of the environment and current difficulties, and a detailed analysis and a review of its relocation needs. The study will also compare potential locations for the current warehouses of the Istanbul Navy Logistics Supply Center. This thesis analyzes the root causes of the current warehouse location problems and compares potential locations by using different location-model techniques. Considering location theories and models is useful in selecting the best site for warehouses [Ref. 2, 3]. Site selection models and their applications are the main purpose of this research. Consequently, this thesis provides recommendations for relocating the current facilities according to strategic goals and for implementing the IT and other current technologies with the Navy's new logistic management system.

This thesis is based on the following methodology:

- A literature review of books, articles, and other library information resources;
- A review of internet resources;

- Phone and e-mail interviews with managers who have supply and logistics experience;
- Data analysis to answer the thesis questions, case study analysis to find the best logistics center location for the Turkish Navy in Istanbul by applying surveys and by using different models;
- Reports of the analysis results.

D. THESIS OUTLINE

Chapter II introduces how to move warehouse operations and how to select sites. The actual decision to move or to stay and the cost of relocating are discussed. Site selection strategies and the constraints are presented as well as constraints.

Chapter III is dedicated to warehouse site selection models. Site selection models are categorized and described briefly. The Logical Decisions for Windows (LDW) as a software program, the Center of Gravity (Minisum) Method and Electré Method are presented in detail since they are applied to analyze the case study in this research.

Chapter IV presents the case study and the related data. The history of the Turkish Navy's current supply center in Istanbul, some important demographic information about the city's economy, current changes in the strategic requirements and the transportation statistics are explained.

Chapter V analyzes the relocation requirement and searches for the best location to suit the Turkish Navy's current needs. The application of the Center of Gravity Method and the Electré Method determines the best location.

Finally, Chapter VI discusses the conclusions, recommendations, and areas for further research.

II. WAREHOUSE SITE SELECTION

A. RELOCATING A WAREHOUSE OPERATION

Ackerman [Ref. 3] states that the user should develop a functional outline for the supply center, which includes a review of the existing customer service needs and how best to achieve this service level. Simulating the costs of operating the center may be a beneficial tool to employ. Simulations of any kind should be employed to the highest extent possible. Finally, the user should develop a detailed plan for opening the facility to allow proper lead times and to minimize confusion during the startup phase [Ref. 3].

Although the actual relocation of a warehouse operation is beyond the scope of this research, the basics of the subject are presented in the following paragraphs.

1. To Move or To Stay

This question may arise when a more desirable building or location becomes available. Some other changes in transportation or other customer service considerations may also be the reason [Ref. 3]. In the case study of this research, selecting an alternative location and evaluating potential changes in the current location are the main reasons for this question. Chapter IV furnishes necessary data about the case.

2. Initial Planning

Pre-planning is essential when building a warehouse from the ground up [Ref. 10]. Early in the planning stages for the supply center, communications, packaging, transportation, security and perishability of the stored products must be considered [Ref. 3].

3. Good Timing

A target date must be set before the actual relocation. This date may be changed, but for planning purposes a target date is essential. Short-term weather forecasts, seasonal and climate factors and seasonal inventory level variations should be considered in time to set the date. The target date can also be essential because estimating the costs of the relocation may vary depending on the proposed relocation period [Ref. 3].

4. Movement Cost Estimation

After a target date is set, an on-hand inventory assessment of that date is necessary. This estimate can simply be calculated as a percentage of the existing inventory level. An important point is to plan the moving date to coincide with a lower inventory level period or to a period when shipping activity is minimal [Ref. 3].

Additionally, how to load trucks, the cost of transferring the load, and the total time needed to move are other issues that require prior considerations. Second in importance to the question of whether or not to relocate is deciding whether to continue services or whether to suspend operations during the move. Customer service considerations and communications are priorities in a warehouse move [Ref. 3]. However, these topics are beyond the scope of this research. The final phase of relocating a warehouse always ends with opening the new warehouse and the supply center according to careful planning.

B. SITE SELECTION CONSIDERATIONS

1. Project Team and Site Selection Strategy

Once it is determined that a warehouse is needed, the next step is to find the right location. Proper selection of the warehouse location is a highly important and complex task [Ref. 3]. Before beginning the project selection, the organizations must assemble a dedicated facility planning team. This team should be formed of qualified personnel according to the project's specific requirements. First of all, this team should define the factors that affect the selection of the site, including service requirements, transportation and inventory costs. The team's site selection strategy usually consists of three levels: macro–analysis, micro–analysis and the specific site selection [Ref. 9].

The macro–analysis determines in what parts of the country the warehouses should be located and defines the significant trade-offs and constraints. The organization can benefit by using various models, including spreadsheet cost calculators, network simulators, and mathematical optimization models [Ref. 9].

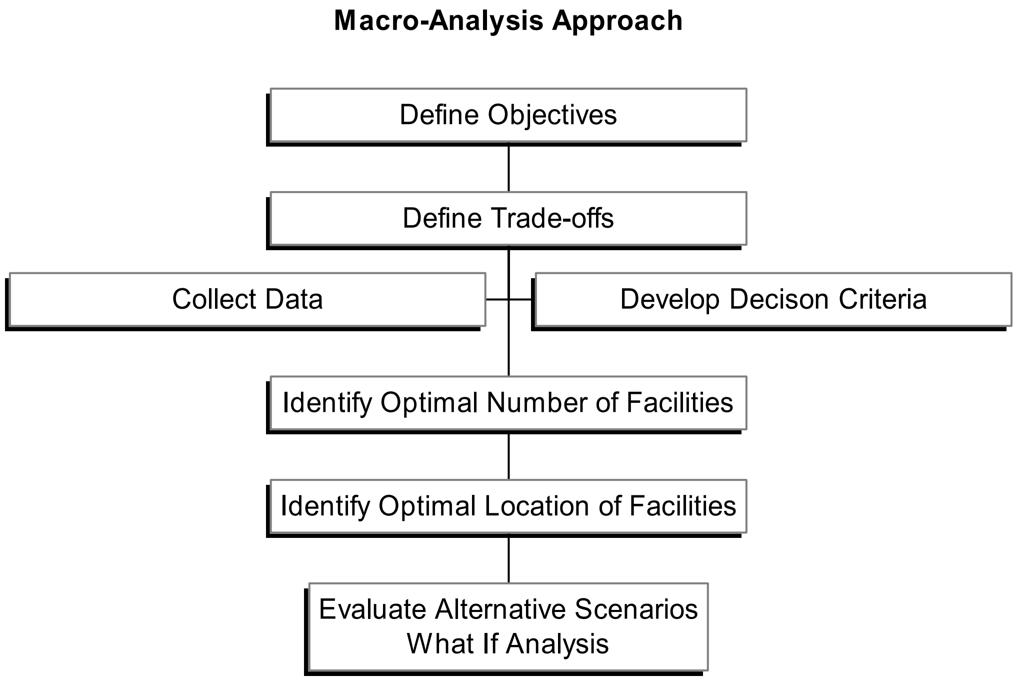


Table 2.1. Macro–Analysis Approach [After Ref. 9]

The outcome of the macro–analysis should be a set of alternative scenarios, and identification of a region or regions, which will meet the site selection objectives [Ref. 9].

The micro–analysis defines a geographic area of the country to locate the new warehouses. The micro–analysis addresses the trade-offs involved in comparing the potential sites within a geographic region. The project team weighs such regional factors as zoning laws, government investment incentives, accessibility to highways, air and rail transportation, utility services, land values, and climate [Ref. 9].

Specific site analysis identifies the particular location where the facility will be. The selected site must meet the objectives. After selecting the final location, the project team must determine whether to erect a new structure or to adapt an existing one [Ref. 9]. Since the "buy vs. build" decisions are beyond the scope of this research, no further information will be provided regarding this issue.

2. Selection Consideration and Constraints

Once all the required data has been collected, the actual analysis can take place. The actual site selection task consists of three steps: Setting priorities, determining the

critical features, and selecting the best location among alternatives that may have both advantages and disadvantages. The final selection of a location will probably consist of some trade-offs [Ref. 1, 2].

The first step is identifying the reasons for a new warehouse location. Sometimes the reason is the need to relocate an existing warehouse because operational objectives change or because stock is increasing [Ref. 3]. The reason may even be security or transportation problems. Determining these reasons defines or narrows the search for a new warehouse location.

Selecting a site is usually difficult and finding an outside consultant may be necessary. Real estate offices, sales representatives, railroad companies, utility companies, government agencies, and also engineers are possible consultants. In addition, assigning a project manager to oversee the location selection is wise [Ref. 2, 3]. Stated succinctly, for a decision of this importance, the best method is often accepting the least risk.

Geographical factors can also substantially affect the utility of a warehouse site. Access conditions can be even more critical when a supply center uses different modes of transportation, such as rail, airways, highway, and water. While roadways offer possibilities for the most extensive geographical coverage, the ability to extend waterways and railways is usually constrained by geography. Climate is another important factor, especially for the energy costs. The possibility that climate will disrupt transportation is also a major consideration. If airfreight service is critical to the operation–as in the case study of this research–the service record of the nearest airport under consideration should be analyzed [Ref. 2].

Eventually, for a successful site search, carefully defining user requirements is vital. A requirement list is a very helpful guide for location decision. Selecting critical features is the next step in choosing a warehouse location [Ref.2, 3]. For example, if reaching customers rapidly is crucial, then the location should be very close to the customer center. On the other hand, if security is more important, choosing a location far from population centers will probably be a better decision. Finally, preparing a list of

alternative locations and the characteristics of these alternatives are other critical considerations.

Transportation highly influences the selection and success of warehouses and is an essential part of the warehousing concept: Goods must be brought to the warehouse and from the warehouse to the customer [Ref. 5]. All warehouses use trucks or railroads, airlines, and waterlines to perform their distribution duties [Ref. 3]. The shipping time and cost heavily depend on the warehouse location and its ability to use various means of transportation easily. Consequently, the specific delivery-time requirements of the organizations must be established before any warehouse locations are determined.

Naturally, connected to the issue of transportation is the distance of the warehouse from each customer center. Normally, the customers served by the warehouse are separated in a region randomly. Creating a model based on optimization methods may minimize the total distance from all customer centers to the warehouses. In addition, while considering the location of the warehouse, forecasting new potential customers should be included in the decision process.

The availability of a rich labor market for the alternative site has usually minor importance, if the proposed operation has a high degree of automation and relatively little touch-labor. On the other hand, labor can be very important in other warehousing operations [Ref. 3].

Taxes can be a critical competitive factor for civilian companies when the warehouse inventory has high value. Variations in taxes, particularly inventory taxes, for different sites, can make the site costly [Ref. 3]. An example of this variation may be seen in free-trade zones and in some metropolitan areas.

Safety and security reasons are also common features for choosing a location. The probability of natural disasters should be researched. For example, in the 1999 Turkish earthquake, much unexpected damage occurred at Naval warehouses due to inadequate inspection of the warehouse locations. Many universities, private companies or government agencies have site safety test services that may be used [Ref. 7].

Security, somewhat different from safety, usually addresses physical security, such as protection against theft. For military and government warehouses, security has more priority than for private warehouses. At times, selecting a site far from a city center may help reduce such problems. Since the value of goods stored in warehouses can be significant, all necessary precautions must be taken before determining the location.

In searching for a supply center warehouse site, finding one that fits a general construction plan is more effective than attempting to adapt construction to the site. For instance, warehouse buildings with odd-shaped walls designed to fit a railroad curve or some other site constraint are usually more costly to operate. Enlargement opportunity of the site is also a critical factor in the planning and selection processes [Ref. 2].

Public utilities around the warehouse location area are becoming very important. Utilities include electricity, water, phone, or sewerage services, etc. Utilities not only affect operating costs, but also influence the risk of spoilage.

Industrial and technological environments are other influential characteristics for warehouse locations. To have the flexibility of easily applying new technologies to the warehouses and of keeping the education level of personnel high, the location should be near industrial or technological centers.

Every site seeker should also carefully study community attitudes toward the new warehouse. This is more important for military facilities since there may be an opposition against military installations in the proposed area. In most communities today, a clean and quiet warehouse development is considered preferable to operations that may cause pollution, congestion or other conditions perceived as detrimental to a community's quality of life. Nowadays, some communities are opposed to any new industrial development, even warehousing [Ref. 3]. This kind of opposition obviously should be considered when one selects potential sites.

Preparing a list of the various constraints is the next phase before starting to eliminate the alternatives. Economic factors are usually the most essential constraints. The most important economic factor to measure in site selection is the cost versus the

value of a new warehouse site [Ref. 2]. Since companies do not have infinite resources to invest in a warehouse, they try to satisfy their needs within their available resources.

With all requirements and critical features defined, the user should now move through the selection process [Ref. 3]. By combining all these considerations, constraints and the advice from consultants, inadequate alternatives can be eliminated. The important issue here is to crosscheck the final proposed location from multi-sources to be sure that it is the best-choice location [Ref. 3].

C. SUMMARY OF SITE SELECTION PROCESS

One of the toughest decisions for a logistics manager is selecting the best location to establish a new warehousing facility. No manager wants to be remembered for locating a new warehousing facility in a ludicrous area, such as the vicinity of a toxic waste dump [Ref. 9]. The first step in the site selection process is to determine the macro-location and reduce it to the micro-location. Doing this is important since it forces the analyst to pursue a specific process of elimination. First, one should determine the largest possible universe that could be considered in selecting the site. Then one must, through elimination, systematically narrow the field as specific alternatives are considered. In narrowing the location from macro to micro, the decision makers should always keep in mind the main reason for seeking a new warehouse site [Ref. 2].

Sources of information must be crosschecked with other sources so that analysts are sure about the final site. If one consultant states that a specific site is earthquake safe with a good history of durability during past earthquakes, at least one other opinion from a trustable, objective and independent consultant should also be obtained.

Other general issues to be considered are zoning, topography, existing buildings or other improvements on the selected site, landscaping, access to the site, storm and sanitary infrastructure, water, sprinklers and other fire protection systems, power, and fuel [Ref. 2]. If any of these issues are ignored, serious problems could develop in the future.

Contingency plans are always quite valuable. Aside from the preferred site, selecting an alternative site, which is almost as good and equally available, is wise. Then

in the event that the bargaining for the preferred site should fail, letting the seller discover that an alternative site exists can improve one's leverage during negotiations [Ref. 2].

As stated previously, site selection for warehouses is one of the most important decisions the related managers ever make. Although most of the decisions are correctable, a poor choice for a warehouse location is a very costly decision to correct [Ref. 2, 3]. In conclusion, before choosing a warehouse location, priorities are set, critical features are determined and finally, alternatives are eliminated. In other words, warehouse location decisions must be taken very carefully.

Appendix A contains a Location Analysis Checklist, a useful aid in analyzing a location [Ref. 3].

III. WAREHOUSE SITE SELECTION MODELS

A. BACKGROUND

Depending on the number of alternative locations, finding the best location can take a tremendous amount of time. Processing huge amounts of data requires decision makers to employ some of the site selection models in the large-scale problems. There are a number of site selection models to assist in analyzing various site selection scenarios [Ref. 11].

Some of the site selection methods are listed below:

1. Mathematical Optimization Models

Linear/Integer Programming Models fall in this category. Each model consists of an objective function and the constraints. The variables must be defined to represent each decision. Models can be concisely expressed using algebraic expressions with subscripted variables. Usually a solver software program can obtain the optimum solution.

2. Software Programs for Decision Analysis

There are some specific software programs designed to assist in making decisions. Logical Decisions for Windows (LDW) is one of them. This program is used in the case study of this thesis and explained in detail later in this chapter.

3. Simulation Models

Simulation is the process of designing and creating a model of a real system for the purpose of conducting numerical experiments to obtain a better understanding of the behavior of that system for a given set of conditions. Nowadays, simulations are usually created on a computer with appropriate software [Ref. 13]. The simulation models are quite economical and help avoid poor investments, but they can be expensive to develop.

4. Location-Allocation Models

Location-allocation modeling was originally developed to solve site selection problems in the public sector for facilities such as schools, fire stations and hospitals. Location-allocation is a very flexible approach, but the decision is usually restricted by the time and the cost required for computation [Ref. 14].

5. Center of Gravity Method

This method is also called the Minisum method. Minimizing transportation costs is quite important in site selection projects for a new warehouse, a logistics center or a new military base. The Center of Gravity method focuses on the transportation costs. Obviously, many other factors must be considered during the process of selecting a site. The Center of Gravity method presents a basic solution to the site selection problems. However, the outcome of this method is still quite valid [Ref. 8]. This method is applied in the case study of this research in Chapter 5.

6. Multi-Criteria Decision-Making Models (MCDM)

Frequently, decision makers face numerous elements on a project that superficially seem mutually exclusive, yet in reality, each component is an intrinsic element of the system as a whole. As a consequence, every component in a system must be evaluated. This task entails many disciplines. Therefore, making decisions about any subject requires an interdisciplinary approach [Ref. 8].

Essentially, decision-making means solving problems. In other words, the decision maker is forever at a dichotomy. Sometimes, simple scientific methods are enough to solve the myriad of dichotomies, at other times, approaching the event multi-dimensionally is necessary [Ref. 8].

A decision maker often uses more than one criteria or objective to evaluate the alternatives in a decision problem. Usually, these criteria conflict with one another. There are many types of multi-criteria problems; they are very common in everyday life. For example, Multi-Criteria Decision-Making (MCDM) methods can be easily applied in choosing government projects, choosing new products, selecting candidates for a professional position, preparing equipment plans, selecting sites for various types of facilities, etc. MCDM refers to making decisions in the presence of these multiple criteria problems. MCDM methods employ multi-dimensional and interdisciplinary approaches [Ref. 8, 12, 15].

MCDM methods are categorized in many different ways. A general list of the commonly used MCDM methods is presented below:

a. Electré Method

Electré was originally developed by B. Roy [Ref. 33, 36] to incorporate the imprecise and uncertain nature of decision-making. Ranking and selecting projects are difficult and complicated tasks because there is usually more than one dimension for measuring the impact of each project and more than one decision maker. The Electré method has several unique features to handle multi-dimensional problems, namely the concepts of outranking and indifference and preference thresholds [Ref. 16, 17]. The Electré method is also employed in the case study of this research in Chapter 5.

b. Weighted Sum Method (WSM)

Hwang and Yoon [Ref. 37] state that this procedure chooses, as the best alternative, the option that obtains the best global performance, as computed using a weighted sum of the performances of the alternatives along each criterion.

c. Multi-Attribute Utility Theory (MAUT)

A technique based on the paradigm of a decision tree and risk analysis based on cardinal utility. MAUT incorporates multiple viewpoints [Ref. 17, 21].

d. Analytic Hierarchy Process (AHP)

T. Saaty [Ref. 20] has proposed AHP as a systematic method for comparing a list of objectives or alternatives. AHP is especially suitable for complex decisions that involve the comparison of decision elements, which are difficult to quantify. AHP assumes that, when faced with a complex decision, the natural human reaction is to cluster the decision elements according to their common characteristics [Ref. 19, 20].

e. Preference Ranking Organization Method (PROMETHEE)

PROMETHEE is based on the same principles as Electré and introduces functions to describe the decision maker's preferences along each criterion. This procedure provides a partial order of the alternatives [Ref. 18].

f. Technique for Order Preference by Similarity to Ideal Solution (TOPSIS)

This procedure chooses, as the best alternative, the option that is closest to an ideal solution and furthest from the worst solution [Ref. 18, 37].

g. *Evidential Reasoning (ER)*

The Evidential Reasoning (ER) approach is not only a method that combines both qualitative and quantitative assessments, but also handles uncertain and imprecise information or data. The state of an attribute (a criterion) may be determined by factors (sub-criteria) at a lower level [Ref. 12].

h. *Factor Rating Method*

This method is mostly used to evaluate the factors, which cannot be evaluated numerically with the other factors. Applying this method includes determining the highest scores for each factor (criterion), determining the various levels of each factor, and determining the appropriate scores for these levels [Ref. 8].

i. *Sorting and Cost Convenience Method*

Although this method does not always conclude with satisfactory solutions, it is still one of the most widely used methods. Applying this method includes assigning weights and scores to each factor, then finding the importance of each alternative location by calculating their total scores [Ref. 8].

B. LOGICAL DECISIONS FOR WINDOWS (LDW)

Logical Decisions for Windows (LDW) is a sophisticated system for evaluating alternatives that differ on a number of evaluation variables or criteria. Alternatives can be anything needed to choose between–jobs, potential employees, factory locations, or even what wine to have for dinner. LDW works best for decisions where many concerns must be considered at once, and where professional and value judgments will play a crucial role [Ref. 32].

LDW uses the judgments and preferences of the decision makers and the stakeholders to rank the alternatives. LDW helps decision makers review their preferences concerning the measures by guiding them through a series of questions. On the basis of their answers, Logical Decisions constructs the formula that ranks the alternatives [Ref. 32].

LDW uses powerful methods from the field of Decision Analysis to help decision makers evaluate the alternatives. Decision analysis was developed in the 1960s and

1970s at Stanford, MIT and other major universities. In particular, Logical Decisions is based on the principles of Multi-Attribute Utility Theory [Ref. 38].

In summary, the following steps describes the development of a LDW model for a decision problem [Ref. 32]:

- Define a set of alternatives to be ranked
- Define measures to describe the alternatives
- Enter the level on each measure for each alternative
- Review your preferences so the measure levels can be combined
- Rank the alternatives and choose the best one.

The parameters that are used when applying this software program in the case study of this thesis research are obtained from the evaluation of two different surveys and the application of LDW is explained in Chapter V.

C. CENTER OF GRAVITY (MINISUM) METHOD

As stated before, the Center of Gravity Method is based on minimizing the total transportation costs. Doing this, the Center of Gravity Method makes two assumptions about the transportation costs [Ref. 8]:

- Transportation cost is the only factor when selecting a site,
- Transportation cost changes proportionally to the transportation distance.

The following data must be known to compute the coordinates of the best location that minimizes the transportation costs [Ref. 8]:

- The amount of cargo to be transported to all customer locations,
- The geographic coordinates of all locations on a specific grid system,
- The unit transportation costs.

The mathematical notations of the variables are as follows [Ref. 8, 34]:

P_i (X_i; Y_i) : The coordinates of the customer location i.

T (X; Y) : The coordinates of the best location.

D (T-P_i) : The distance between location T and P_i, (km).

C_i : The transportation cost to carry one unit load to one unit distance between T and $P_{i,}$ (Cost/kg*km).

Q_i : The amount of load to transport between T and $P_{i,}$ (kg).

N : The number of customer locations.

TC : The total transportation cost (Turkish Lira=TL).

The objective function is defined as below:

$$TC_{min} = \sum_{i=1}^{n} [C_i * Q_i * d\,(T\text{-}P_i)]. \tag{1}$$

The objective of this method is finding the coordinates of the location T (X; Y) that minimize the total transportation costs. $C_{i,}$ Q_i and n are constant values. The only variable is the distance: d (T-P_i). The distance can be calculated in three different ways [Ref. 34,35]:

a. Rectilinear Distance

Used for ground transportation when a rectilinear street network or aisle network needs to be considered. The rectilinear distance between the best location and the customer locations is calculated as follows [Ref. 34]:

$$d\,(T\text{-}P_i) = |X - X_i| + |Y - Y_i|. \tag{2}$$

b. Linear (Euclidean) Distance

Used for air transportation since the distances are assumed to be linear for this type of transportation. The linear distance between the best location and the customer locations is calculated as follows [Ref. 34]:

$$d\,(T\text{-}P_i) = \sqrt{\left[(X - X_i)^2 + (Y - Y_i)^2\right]} = \left[(X - X_i)^2 + (Y - Y_i)^2\right]^{1/2}. \tag{3}$$

c. Square of Linear Distance (Centroid Problem)

In linear distance problems the convex hull is a line segment. The cases where convex hull is not a line segment, the distances are obtained by squaring each Euclidean (linear) distance. Finding a location to minimize the transportation costs from the square of linear distances is called the centroid problem. The solution to the centroid problem is called the centroid. The centroid is the unique new facility location that

minimizes the transportation cost function. The contour sets of this function are quite simple; in fact, it is known that contour sets are disks, each with an optimum point as a center. Thus the contour sets are particularly simple to construct, and just as with the rectilinear distance problem, are useful in evaluating other possible locations for the new facility. The closer the new facility can be to the centroid location, the better the solution will be. The distances are obtained from the following formula for this method [Ref. 34]:

$$d\,(T\text{-}P_i) = (X - X_i)^2 + (Y - Y_i)^2. \tag{4}$$

The case study of this research is a Turkish Navy military supply center relocation problem in Istanbul. This military supply center is not using air transportation for the customer deliveries. Therefore, only the rectilinear distance and the square of linear distance methods will be explained in details.

1. Calculation with the Rectilinear Distance [Ref. 8, 34]

W_i is the transportation cost of carrying the entire load of customer "i" (P_i) to one unit distance between T and P_i. In short, "W_i" will be called "the weighted load values" and represented with the following formula:

$$W_i = C_i * Q_i. \tag{5}$$

The formula for the total transportation cost is below:

$$TC = \sum_{i=1}^{n} [W_i * (|X - X_i| + |Y - Y_i|)]$$

$$TC = \sum_{i=1}^{n} (W_i * |X - X_i|) + \sum_{i=1}^{n} (W_i * |Y - Y_i|)$$

$$TC = \text{Min } f(x) + \text{Min } f(y).$$

f (x) is the total cost of transportation in the x-direction and f (y) is the total cost of transportation in the y-direction. Thus the minimum total cost can be obtained by solving the two independent problems of minimizing the cost of transportation in the x-direction and minimizing the cost of transportation in the y-direction.

The X and Y values minimizing both functions are obtained from the following formulas:

$$\text{The largest cumulative sum of } W_i \text{ value} < ½ * \sum_{i=1}^{n} W_i \quad (6)$$

and

$$\text{The smallest cumulative sum of } W_i \text{ value} \geq ½ * \sum_{i=1}^{n} W_i \quad (7)$$

W_m is the cumulative weighted load value (cumulative sum of W_i) that satisfies the inequalities of (6) and (7). When W_m is greater than the median ($½ * \sum_{i=1}^{n} W_i$), the coordinates of the best site are the X and Y median values, which belongs to the W_m value (m^{th} X value=X_m and m^{th} Y value=Y_m). If W_m is equal to the median, then these coordinates are expressed as an interval: $[X_m, X_{m+1}]$ or $[Y_m, Y_{m+1}]$. An example of the calculation is explained later in this chapter.

The following steps are used to determine the best location:

- Create a data table to find the abscissa (X) and another table to find ordinate (Y) of the best location,
- Sort ascending the abscissa and ordinates of the demand centers,
- Calculate the W_i (C_i*Q_i) value of the customer locations,
- Calculate the cumulative sum of W_i values and list in a column on the data table,
- Calculate $\sum W_i$ (the total of all weighted load values),
- Calculate the median ($½ \sum W_i$) value,
- Find the number that is equal to the ($½ \sum W_i$) from the cumulative sum of W_i column. If the ($½ \sum W_i$) value does not exist in the cumulative sum of W_i, then find the number that is closest in value to the ($½ \sum W_i$) but greater than ($½ \sum W_i$). The abscissa and ordinate values in these rows give the point T (X; Y), which minimizes the total transportation costs.

2. Calculation with the Square of Linear Distance [Ref. 8, 34]

W_i ($W_i=C_i*Q_i$) represents the same weighted load values in this method.

The distance function between T and P_i locations is:

$$d\,(T\text{-}P_i) = (X-X_i)^2 + (Y-Y_i)^2.$$

Thus, the total transportation cost function is represented as below:

$$TC = \sum_{i=1}^{n} \{W_i * [(X-X_i)^2 + (Y-Y_i)^2]\}.$$

The T (X; Y) point, which minimizes this function, must satisfy the following conditions:

$$\partial TC/\partial X = 0 \quad \text{and} \quad \partial TC/\partial Y = 0.$$

The coordinates of the best location are obtained by setting the above partial derivatives to zero (0). Consequently, the abscissa (X) and the ordinate (Y) of the best location are derived and represented as below:

$$\frac{\partial TC}{\partial X} = 2\sum_{i=1}^{n} W_i (X - X_i) = 0$$

$$= X\sum_{i=1}^{n} W_i - \sum_{i=1}^{n} (W_i X_i) = 0$$

$$X\sum_{i=1}^{n} W_i = \sum_{i=1}^{n} (W_i X_i)$$

and $X = \dfrac{\sum_{i=1}^{n}(W_i X_i)}{\sum_{i=1}^{n} W_i}$. Y is calculated in the same way and $Y = \dfrac{\sum_{i=1}^{n}(W_i Y_i)}{\sum_{i=1}^{n} W_i}$.

3. Rectilinear and Square of Linear Distance Example

The following scenario is based on hypothetical data: The Golcuk Logistics Center Command is the main supply center of the Turkish Navy. This center supports and transports supplies to seven local supply commands. The location of these commands on the coordinate system, the annual load quantities to be carried between these commands and the main logistics center, and the unit transportation costs are listed in Table 3.1. When a relocation project is considered for the Golcuk Logistics Center

Command to minimize the transportation costs, the rectilinear distance and the square of the linear distance methods must be used to find the best location.

Location	**Coordinate**	**Annual Load (Q_i – kg)**	**Cost (C_i – TL/kg*km)**
Istanbul	P_1 (3; 4)	40,000	5
Izmir	P_2 (3; 10)	30,000	10
Canakkale	P_3 (8; 2)	10,000	10
Marmaris	P_4 (10; 10)	30,000	9
Erdek	P_5 (14; 6)	10,000	7
Iskenderun	P_6 (14; 7)	20,000	5
Eregli	P_7 (16; 6)	20,000	7

Table 3.1. Summary of Example

The goal is finding the coordinates of the best location for the Logistic Center Command that minimizes the total transportation costs.

$$TC_{min} = \sum_{i=1}^{n} [C_i * Q_i * d(T\text{-}P_i)].$$

$$W_i = C_i * Q_i.$$

a. Solution to the Rectilinear Distance Situation

The following table must be formed to find the best location. The coordinates of the best location are designated in Table 3.2.

ABSCISSA $X_0=[8,10]$					
Location	**X_i**	**C_i(TL)**	**Q_i (x1000 Kg)**	**W_i**	**Cumulative Sum of W_i**
Istanbul	3	5	40	200	200
Izmir	3	10	30	300	500
Canakkale	8	10	10	100	**600**=1/2*1,200
Marmaris	10	9	30	270	870
Erdek	14	7	10	70	940
Iskenderun	14	6	20	120	1,060
Eregli	16	7	20	140	**$\sum W_i$ = 1,200**

ORDINATE $Y_0=7$					
Location	**Y_i**	**C_i(TL)**	**Q_i (x1000 Kg)**	**W_i**	**Cumulative Sum of W_i**
Canakkale	2	10	10	100	100
Istanbul	4	5	40	200	300
Eregli	6	7	20	140	440
Erdek	6	7	10	70	**510**<1/2*1,200
Iskenderun	7	6	20	120	**630**>1/2*1,200
Izmir	10	10	30	300	930
Marmaris	10	9	30	270	**$\sum W_i$ = 1,200**

Table 3.2. Calculation of the Best Location with the Rectilinear Distance

The abscissa table is in ascending abscissa (X_i) order, and the ordinate table is in ascending ordinate (Y_i) order in Table 3.2. The sum of W_i ($\sum W_i$) is 1,200 and the median value of cumulative sum is:

$½*\sum W_i=600.$

Since the median value ($½*\sum W_i=600$) exists in the cumulative sum of W_i column of the abscissa table, the abscissa of the best location will be expressed within an interval. The abscissa value on the corresponding row is the lower limit of the interval ($X_i=8$) and the upper limit is the $X_i=10$, which must be adjacent to and greater than the

lower limit of the interval (10>8). Consequently, the abscissa of the best location is any value within the interval of [8,10].

The median value ($\frac{1}{2}*\sum W_i=600$) does not exist in the cumulative sum of W_i column of the ordinate table. Therefore, the smallest number, which is greater than the median value ($\frac{1}{2}*\sum W_i=600$), must be chosen and this number is 630. Consequently, the ordinate of the best location is $Y_i=7$, which is the corresponding ordinate value on the same row with the value of 630.

For example T (8; 7) is one of the best location coordinates, and the total transportation cost for this point is

$$TC = \sum [W_i * (|X-X_i| + |Y-Y_i|)]$$

$$TC = (200 * |8-3| + 300 * |8-3| + 100 * |8-8| + 270 * |8-10| + 70 * |8-14| + 120 * |8-14| + 140 * |8-16| + 100 * |7-2| + 200 * |7-4| + 140 * |7-6| + 70 * |7-6| + 120 * |7-7| + 300 * |7-10| + 270 * |7-10|) * 1000 \text{ TL}$$

TC = (1000 + 1500 + 0 + 540 + 420 + 720 + 1120 + 500 + 600 + 140 + 70 + 0 + 900 + 810) * 1000 = 8,320,000 TL (*The minimum*).

The total cost value remains the same for all the abscissa values within the interval limits. Total cost is 8,320,000 TL for all T (X; Y)= T (8; 7), T (9; 7), and T (10; 7) coordinates; therefore all of these locations are the suitable locations.

b. Solution to the Square of Linear Distance Situation

Applying the Square of Linear Distance Method formula,

$\sum(W_i*X_i)$ = 200*3 + 300*3 + 100*8 + 270*10 + 70*14 + 120*14 + 140*16 = 9900,

$\sum(W_i*Y_i)$ = 100*2 + 200*4 + 140*6 + 70*6 + 120*7 + 300*10 + 270*10 = 8800,

$\sum W_i$ = 200 + 300 + 100 + 270 + 70 + 120 + 140 = 1200,

and

$X = \sum(W_i * X_i) / \sum W_i = 9900 / 1200 = 8.25$

$Y = \sum(W_i * Y_i) / \sum W_i = 8800 / 1200 = 7.33.$

Consequently the coordinates of the best location, which minimizes the transportation costs is

T (X; Y) = T (8.25; 7.33).

D. ELECTRÉ METHOD

1. Background

Bernard Roy [Ref. 33, 36] conceived the Electré method in 1966 in response to the deficiencies of the existing decision-making methods. This method has evolved through a number of versions (I through IV); all are based on the same principles but are operationally somewhat different [Ref. 16].

The Electré method may not always be the best decision aid; however, it is a proven approach. It has several unique features not found in other methods, including the concepts of outranking, as well as indifference and preference thresholds. Additionally, the Electré method can especially be used to convert qualitative data to quantitative [Ref. 8, 16].

With its dynamic characteristics, this method may be applied successfully to many problems. However, to obtain reliable results from this method, a decision maker must define the problem broadly, identify the main constraints, and most importantly identify the primary objective. Next, a decision maker should establish an interdisciplinary committee to address the problem, and the members of this committee should be experts in various fields related to the problem. This committee must have experience and the ability to handle the problem with an interdisciplinary approach. They must be unbiased. Likewise, the decision maker must eschew personal bias that could deviate the interdisciplinary committee from the primary objective [Ref. 8, 33].

Using the Electré method, the interdisciplinary committee generally follows the guideline given below to select the best location [Ref. 8, 33]:

- Identify the alternative locations,
- Identify the important criteria of the problem,

- Assess each alternative location according to each criterion
- Employ the Electré method to solve the problem.

2. Explanation of the Electré Method on an Example [Ref. 8]

The Electré method will be applied to a site selection problem. Alternative locations (options) and criteria will be shown with symbols. The following steps are used to solve the problem.

a. Step1: Identifying the Options [Ref. 8, 33]

There will be five alternative locations in this example problem. These alternatives (options) are represented by the following symbols: A, B, C, D, and E. These locations may be proposed for a supermarket, a hospital, an appliance main depot, etc.

b. Step 2: Identifying the Criteria [Ref. 8, 33]

Some of the criteria defined by the interdisciplinary committee may include:

1. Transportation
2. A supply of temporary labor
3. The potential for maintaining a stable workforce
4. Enlargement opportunity
5. The populace's response to the project
6. Integration availability to the existing facilities
7. Closeness to raw material or supply
8. Water supply
9. Suitability of transportation facilities and costs
10. The culture and advantages of a metropolitan area
11. Closeness to markets
12. Sewage and garbage service
13. Proximity of universities as a source of high-caliber work force

14. Advertising availability

15. Topography of the site

16. Energy and electricity availability

17. Employer-employee relations

18. Fuel and heating and cooling expenses.

The criterion list can be expanded according to the particular characteristics of the problem. However, the example problem in this chapter will consist of only five criteria. These five criteria are represented by a, b, c, d, and e.

c. Step 3: Weighing the Criteria [Ref. 8, 33]

Weighing the criteria is one of the most vital points of this method. The interdisciplinary committee will sort the criteria by their levels of importance and score each criterion by considering the primary objective.

d. Step 4: Determining Scales [Ref. 8, 33]

Instead of using numerical grades to evaluate the options according to the criteria, the options must be evaluated with the qualitative measures, such as: "Very good, good, not bad, bad, very bad." Next, these qualitative results will be converted to numerical values according to the predetermined scales. The upper and lower limits of the scales will match the "very good" and "very bad," and the intermediate values (good, not bad, bad) will be calculated with the interpolation. For example, a scale from 10 to 0 can be represented as below:

- Very good : 10.0
- Good : 7.5
- Not bad : 5.0
- Bad : 2.5
- Very bad : 0.0

The committee must adhere to the following requirements about the scales:

- There must be as many different scales as the number of different weights, which are determined during Step 3.

- The scale range of the highest weight must be the largest, and the scale range for the lowest weight must be the narrowest. Accordingly, the scale range of lower weights must be a subset of the scale ranges of higher weights. For example, assume that very important criterion "a" has a weight of 4, less important criteria "b and d" have a weight of 2, and the least important criteria "c and e" have a weight of 1. In this example, the scale ranges are chosen as 0 to 10 for "a," 2 to 8 for "b and d," and 3 to 7 for "c and e" (Table 3.3). The ranges can be chosen differently as long as the range of less important criteria is a subset of the higher important criteria. For example, when an option is evaluated as Very Good for two different criteria that have different weights (importance level), this option will get a higher score from the more important criterion and a lower score from the less important criterion. The number of different scales with different ranges is equal to the number of different weights used in the problem.

	Criterion a	Criteria b-d	Criteria c-e
Very Good	**10.0**	**8.0**	**7.0**
Good	7.5	6.5	6.0
Not Bad	5.0	5.0	5.0
Bad	2.5	3.5	4.0
Very Bad	**0.0**	**2.0**	**3.0**

Table 3.3. Determining Scales [From Ref.8]

e. Step 5: Evaluating Options Regarding Criteria [Ref. 8]

Each option is evaluated regarding all the criteria. In the example problem, the options "A, B, C, D, E" are evaluated regarding to criteria "a, b, c, d, e" (Table 3.4).

		Options						
		A	B	C	D	E	Weight	Scale
Criteria	a	5.0	5.0	2.5	7.5	2.5	4	0-10
	b	2.0	3.5	6.5	8.0	5.0	2	2-8
	c	7.0	3.0	5.0	6.0	7.0	1	3-7
	d	6.5	8.0	6.5	2.0	5.0	2	2-8
	e	4.0	6.0	5.0	4.0	6.0	1	3-7

Table 3.4. Evaluating Options Regarding Criteria [From Ref. 8]

f. Step 6: Forming the Concordance and Discordance Matrices

The fundamental assumption of the Electré method is the existence of an outranking operation between two options. For example, one defines option A to outrank option B if the following two conditions are fulfilled [Ref. 22]:

1. A is better or at least as good as B with respect to a major subset of the criteria,
2. A is not much worse than B with respect to the remaining criteria.

The first condition is a concordance condition and the second condition is a discordance condition [Ref. 22].

For the example problem, the concordance matrix value of "E outranks B" assumption is calculated as below [Ref. 8].

- Compare column E values of Table 3.4 with column B values.
- Find the criteria in which the score of option E is equal or greater than the score of option B [using Table 3.4, E is at least as good as B for criterion b (5>3.5), criterion c (7>3), and criterion e (6=6)].
- Calculate the sum of the weights of these criteria and divide it by the sum of all the weights of criteria. The weights of the criteria are respectively 2, 1, and 1 for criteria b, c, and e. The sum of these weights is 4, and it is divided by the sum of

the weights of all the criteria (10=4+2+1+2+1). Therefore the concordance matrix value for this assumption is 0.4 (4/10).

- Write this value in the intersection cell of Row B and Column E on the concordance matrix.

The complete concordance matrix is presented below:

	A	**B**	**C**	**D**	**E**
A	*	0.90	0.50	0.70	0.40
B	0.50	*	0.30	0.70	**0.40**
C	0.70	0.70	*	0.70	0.60
D	0.40	0.30	0.30	*	0.40
E	0.70	0.70	0.80	0.60	*

Table 3.5. Concordance Matrix [From Ref. 8]

In the example problem, the discordance matrix value of "C outranks A" assumption is calculated as below [Ref. 8].

- Compare column C values of Table 3.4 with column A values.
- Find the criteria that the score of option C are less than the score of option A [using Table 3.4, the score of option C is less than option A for the criterion a (2.5<5) and criterion c (5<7)].
- Subtract the scores of option A from the scores of option C and determine the greatest deviation among these pairs of scores [(5-2.5=) 2.5 and (7-5=) 2; therefore the greatest deviation is 2.5 (2.5>2)].
- Divide the greatest deviation by the largest scale range (10 – 0 = 10). This value is the discordance indicator for the C outranks A assumption and will be inserted in the intersection cell of row A and column C (0.25=2.5/10).

- Note this value (0.25) in the intersection cell of Row B and Column E on the concordance matrix. The outcome is called the first discordance matrix (s=1) ("s" is the discordance parameter).

The completed first discordance matrix is presented below:

	A	**B**	**C**	**D**	**E**
A	*	0.40	0.25	0.45	0.25
B	0.20	*	0.25	0.60	0.30
C	0.45	0.30	*	0.45	0.15
D	0.60	0.45	0.50	*	0.50
E	0.30	0.40	0.20	0.30	*

Table 3.6. First Discordance Matrix [From Ref. 8]

If one option is much worse than another option (high discordance), then the outranking assumption between these two options will automatically be penalized. However, this may not be a favorable situation because the discordance indicator can meet the second condition when the second discordance matrix (s=2) is formed. The second discordance matrix helps to control the results of the first discordance matrix. The following steps are used to calculate the second discordance matrix (s=2) [Ref. 8]:

- Follow the first two steps in the concordance procedure above.
- Subtract the scores of option A from the scores of option C and determine the second greatest deviation among these pairs of scores. If the previous deviation (greatest deviation = 2.5) is the only deviation between the grades of the option pair, then the discordance indicator will be zero (0). Similarly, if the previous deviation (2.5) is equal to the second greatest deviation between the grades of the option pair, this deviation will be used to calculate the discordance indicator again. For the example problem, (5-2.5=) 2.5 and (7-5=) 2; therefore the second greatest deviation is 2.

- Divide this value by the largest scale range (10 – 0 = 10). This value will be presented in the intersection cell of row A and column C of second discordance matrix (s=2). For the example problem, this value is 0.2 (2/10).

The completed second discordance matrix (s=2) is presented below:

	A	**B**	**C**	**D**	**E**
A	*	0.0	0.20	0.10	0.15
B	0.15	*	0.15	0.20	0.25
C	0.10	0.20	*	0.10	0.15
D	0.25	0.30	0.15	*	0.30
E	0.20	0.15	0.10	0.20	*

Table 3.7. Second Discordance Matrix [From Ref. 8]

g. Step 7: Electing and Decision

Before determining the best option, the threshold and nucleus concepts must be explained. There are two kinds of thresholds: the preference threshold (p) and the indifference threshold (q). The decision maker specifies the indifference thresholds. The choice of appropriate thresholds is not easy, but realistically, non-zero values should be chosen for p and q. While the introduction of this threshold goes some way toward incorporating how a decision maker actually feels about realistic comparisons, a problem remains. There is a point at which the decision maker changes from indifference to strict preference. Conceptually, there is good reason to introduce a buffer zone between indifference and strict preference, an intermediary zone where the decision maker hesitates between preference and indifference. This zone of hesitation is referred to as "weak preference", and is modeled by introducing a preference threshold, p. Thus, the Electré Method is proposed as a double threshold model [Ref. 16].

Using the thresholds, the following preference relation can be defined for A outranks B assumption: If the concordance indicator (value in the concordance matrix) of this option pair is greater than or equal to "p" and the discordance indicator is less than

or equal to “q,” then A is preferred to B. These two conditions are reviewed for all pairs and the results will be shown in the solution figure. In this figure, each option is represented with a node and each option pair is connected with an arrow that points from the outranking (preferred) option to the other one. Thus, there will be two types of nodes in the chart, one of which is the node with at least one arrow-entering and the other type is a no-arrow-entering node. No-arrow-entering nodes are called nucleus. If a node is not connected to any other nodes, this node can also be an element of the nucleus. However, this situation can be risky and misleading and should be resolved [Ref. 8].

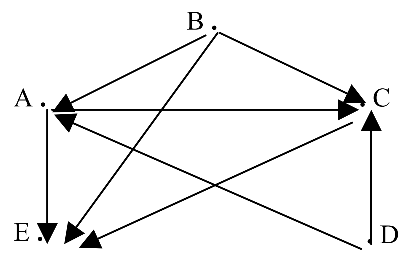
The actual solution process begins with the first concordance and discordance matrices (s=1) and the beginning threshold values are chosen. In the example problem, the beginning thresholds are chosen as p=0.7 and q=0.45 (notation: 0.7/0.45/1). If the discordance indicator is equal to 0.45 or less in the first discordance matrix, and the concordance indicator in the corresponding cell of the concordance matrix is also equal to 0.7 or greater, then this cell will be marked with “*” in the solution figure. This comparison is repeated for the entire concordance and discordance matrices. The results of the example problem are shown in Figure 3.1. B and D options (alternatives) are the two nuclei of the first iteration because no arrow is entering these nodes. Since there must be only one nucleus node, the indifference threshold (q) is increased to 0.6 in this example (notation: 0.7/0.6/1). This situation is shown in the second part of Figure 3.1. After this iteration, the only nucleus will be the option D [Ref. 8].

The second discordance matrix (s=2) is used to control this result. When the discordance parameter is increased from s=1 to s=2, then the values of the discordance indicators in the discordance matrix will decrease. Therefore, decreasing the value of the indifference threshold q is wise. The indifference threshold is chosen as q=0.15 and preference threshold is not changed (p=0.7) (notation: 0.7/0.15/2). If the discordance indicator is equal to 0.15 or less in the second discordance matrix and also the concordance indicator in the corresponding cell of the concordance matrix is equal to 0.7 or greater, then this cell will be marked with “*” in the third part of Figure 3.1. The B and D options (alternatives) are again the two nuclei of the third iteration. Since there must be only one nucleus node, the indifference threshold (q) is increased to 0.2 in this

example (notation: 0.7/0.2/1). This situation is shown in the last part of the Figure 3.1. After this iteration, the only nucleus will be the option D again. This result is consistent with the first finding. Therefore the final location should be option D [Ref. 8].

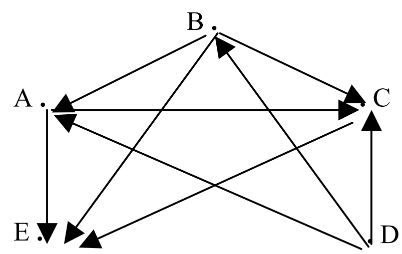
	A	B	C	D	E
A		*		*	
B					
C	*	*		*	
D					
E	*	*	*		

(0.7/0.45/1)



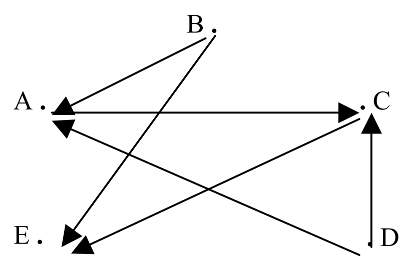
	A	B	C	D	E
A		*		*	
B				*	
C	*	*		*	
D					
E	*	*	*		

(0.7/0.6/1)



	A	B	C	D	E
A		*		*	
B					
C	*			*	
D					
E		*	*		

(0.7/0.15/2)



	A	B	C	D	E
A		*		*	
B				*	
C	*	*		*	
D					
E	*	*	*		

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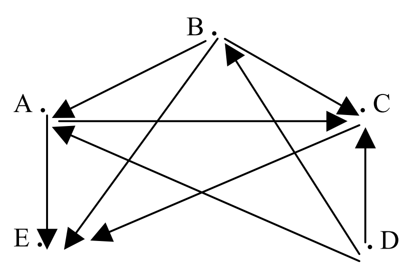

Figure 3.1. Results [From Ref. 8]

3. Conclusion

The Electré method is a dynamic method that is used to solve multi-criterion problems. Forming an interdisciplinary committee is highly recommended for Electré method applications. The committee and the decision maker can also employ consultants when necessary to evaluate the options of the project.

Owing to its dynamic perspective, the Electré method can prevent most of the drawbacks of the other decision-making processes.

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IV. CASE STUDY: ISTANBUL SUPPLY GROUP COMMAND RELOCATION REVIEW

A. BACKGROUND

The Istanbul Supply Group Command is one of the eleven logistics centers in the Turkish Navy. It is located in Kasimpasa on the European side of Istanbul. The primary mission of this center is to support the Navy facilities and ships in Istanbul. The other mission of this logistics center is shipping all necessary items to other logistics centers around Turkey. The mission of the Istanbul Supply Group Command is very dynamic and crucial to the success of the Turkish Military Forces. Its strategic location is critical in performing its mission. In the following pages, various maps are presented to illustrate the locations and transportation modes (roads, bridges, railways, airports, and ports).

This logistics center is a complex facility that includes eleven warehouses. The main items stocked in this center are listed below:

- Military Clothing and Textiles
- Food and Kitchen Appliances
- Office Furnishings
- Stationery
- Medicine and Health Equipment
- Petroleum fuel (diesel, unleaded, leaded and premium gasoline).

Since the current facilities are more than fifty years old, aging problems have significantly reduced the capabilities of this logistics center. The technology is obsolete and modernizing would no longer be cost effective. Similarly, the location does not meet the Navy's current requirements. When the facilities were first built, the transportation and accessibility to the site were quite easy and convenient. The logistics center was far from the densely populated and settlement areas around Istanbul. Today, the current location is in the middle of a settlement area, which, owing to increasing immigration, is highly populated. Therefore, the current land restrictions provide no opportunities for

enlarging the facilities. In fact, the accessibility of large and long transportation vehicles to the current location is one of the greatest problems. The narrow streets that surround the current location will not allow long trucks easy access. Also, reaching the highway from the current location takes a long time due to heavy traffic. Additionally, large commercial trucks are not allowed to travel inside the city limits of Istanbul during daylight hours. However, these trucks are allowed to travel on the highways. This regulation affects the access and deliveries to the Istanbul Supply Group Command. Figure 4.1 is a satellite picture of the European side of Istanbul that shows the main roads and the settlement density around the current location of the logistics center.

Figure 4.1. The Satellite Picture of the Current Location [From Ref. 24]

Figure 4.2 shows the location of the current logistics center and the main roads.

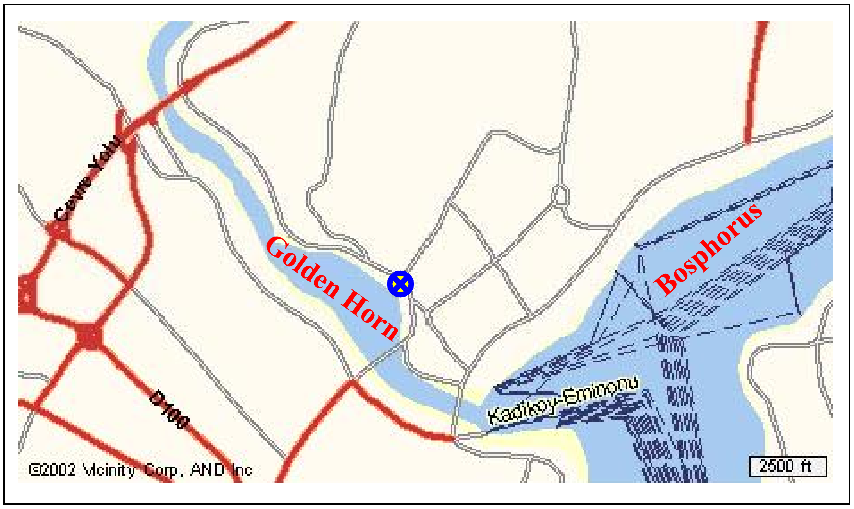

Figure 4.2. The Map of the Current Location and the Main Roads [From Ref. 25]

As depicted on the map, the Golden Horn (Halic) is the extension of the Bosphorus and there are two bridges to access the current logistics center from the Bosphorus. Since these bridges are very low, they restrict the access to the current logistics center for large ships. Only small fishing boats can pass under these bridges. Therefore, the Istanbul Supply Group Command must use another municipal port or ground transportation for water and petroleum transportation.

The following sections present some data about Istanbul and the issues related to relocating the Istanbul Supply Group Command.

1. Background Information about Istanbul

Istanbul is the only city in the world built on two continents. It straddles the Bosphorus Strait, with one foot in Europe and the other in Asia. The two sides of Istanbul are connected by two suspension bridges [Ref. 29].

Figure 4.3. The Location of Istanbul [From Ref. 26]

Istanbul, a large and extraordinary city, has an area of 5,712 km^2 with a population of 9,198,809 (1997). It is the twenty-fourth largest city in the world. Roughly one out of every seven citizens in Turkey lives in Istanbul [Ref. 27].

Though not the administrative capital of Turkey, Istanbul, in terms of decision-making and administration, is the economic and cultural heartland of the modern Republic of Turkey. Istanbul is the major seaport of Turkey as well as its largest city. As the hub of Turkey's industry, the largest companies, banks, insurance and stock exchange firms, advertising companies and mass media are all located in Istanbul [Ref. 27].

Some of Istanbul's economic indicators for 1997 are as follows. The percentages represent Istanbul's share in Turkey's total:

- GDP: 22.8%
- Public Investments: 39.8%
- Consolidated Budget Tax Income: 37.5%
- Income Tax Payers: 21.6%
- Value Added Tax (V.A.T.) Payers: 24.6%
- Corporation Tax Payers: 37.1%
- Bank Deposits: 44.1%
- Agricultural Production Value: 10.6%
- Motor Vehicles: 19.4%
- Private Cars: 24.8%.

Istanbul is also an important tourist center. In 1995, one out of every four foreign visitors to Turkey visited Istanbul [Ref. 27].

As mentioned in the Electré Method in Chapter 3, the cultural environment is a decision criterion for warehouse site selection projects. Istanbul is a very appropriate city for this criterion since it is the cultural capital of Turkey. As the conveyors of modern and popular culture, all of the national TV channels, almost all of the national radio stations and the national newspapers, all of the advertising agencies, and most of the publishing houses are located in Istanbul.

In terms of income allocation, the richest 20% of Istanbul's population earn 64% of the total income, and the poorest 20% earn only 4% of the total income. The literacy of the Istanbul population is above the national average. The literacy rate for children six-years and older is 90%. Also 5.5% of the population has a bachelor's degree [Ref. 27].

There are two airports: one is the Ataturk Airport on the European side and the other is the Kurtkoy Airport on the Asian side. The Port of Haydarpasa is one of the largest ports in Turkey. Both sides of Istanbul have railways, which transport cargo and passengers. The Sirkeci Rail Station is on the European side and the Haydarpasa Rail Station is on the Asian side. The following figure shows the locations of the main transportation centers in Istanbul.

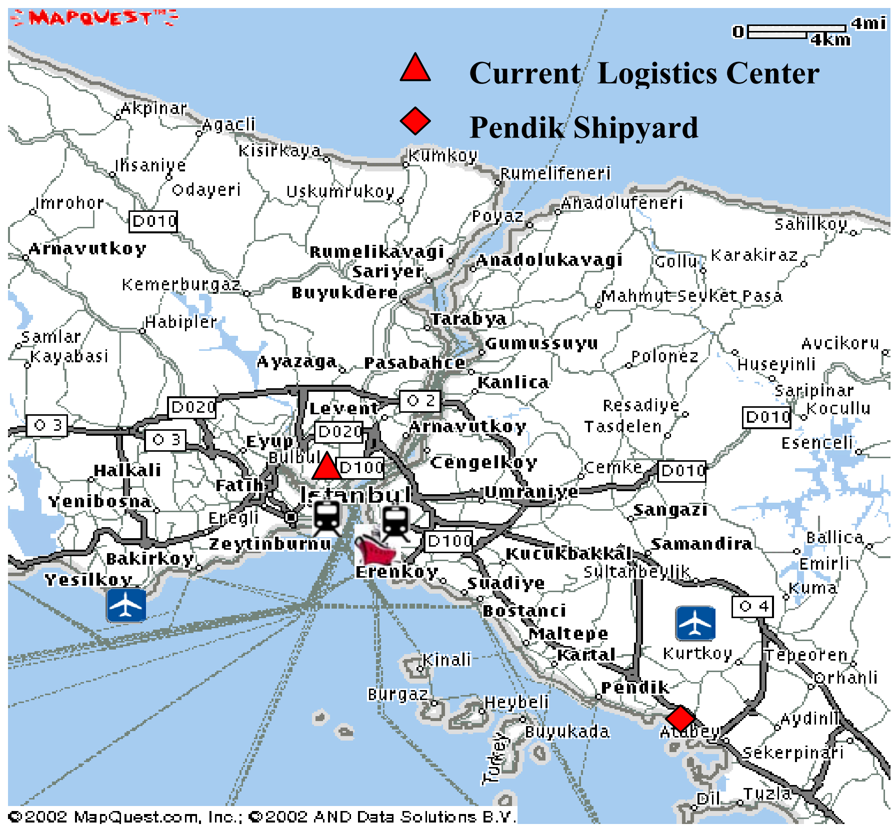

Figure 4.4. Main Locations in Istanbul [From Ref. 30]

2. Effects of 1999 Earthquake on the Current Logistics Center

The damage created in the 1999 earthquake in Turkey has affected the Turkish Navy significantly. Likewise, the earthquake damaged the Istanbul Supply Group Command buildings and infrastructure extensively. According to the damage reports, the current facilities must undergo major retrofitting to make them earthquake safe. The Istanbul Maintenance, Repair and Settlement Command calculated the restoration cost of the current facilities and the cost of building a new logistics center as shown below:

Restoration Cost of Current Facilities	Cost of Building A New Logistics Center
5,571,034,542,000 TL	7,464,000,000,000 TL
$ 8,985,000	$ 12,038,000
TL: Turkish Lira	$1=620,000 TL (Dec 2000)

Table 4.1. Restoration and New Logistics Center Building Costs

The existing logistics center's restoration cost includes the repair of piers and roads as well as the structural reinforcement of buildings to make them earthquake safe and able to meet modern environmental standards.

3. Effects of 1999 Earthquake on the Navy Shipyards

Due to the extensive damage in the Golcuk Shipyard, which was located in the epicenter of the 1999 earthquake, the Turkish Navy has bought a shipyard in Pendik–a suburb of Istanbul. Pendik is located on the Asian side of Istanbul. Furthermore, the Turkish Navy transferred all the operations of the Taskizak Shipyard to the Pendik Shipyard and closed the Taskizak facilities. The Taskizak Shipyard was located next to the Istanbul Supply Group Command. The following figures show the location, layout and surrounding roads of the Pendik facilities.

Figure 4.5. Location and Main Roads around the Pendik Facilities [From Ref. 25]

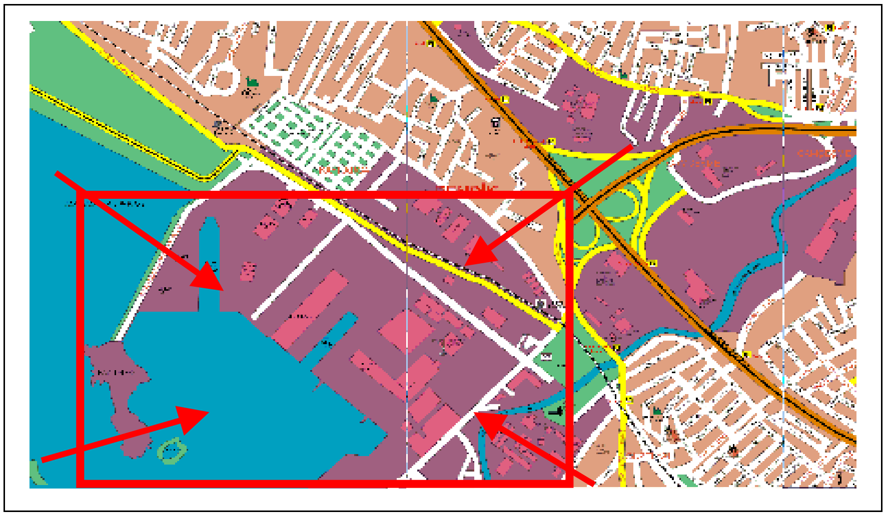

Figure 4.6. Close Map of the Pendik Facilities and Vicinity [From Ref. 28]

4. Alternative Locations for the Current Logistics Center

There are four alternative locations (Appendix B) in Istanbul where The Turkish Navy can build a large logistics center: Beykoz, Sariyer, Pendik and the current location. The Turkish Navy owns parcels of land varying in size and there are different Navy commands on these locations. Sariyer and Beykoz have two smaller supply commands (warehouses) than the Kasimpasa Supply Center. The supply command at Sariyer serves the Turkish Coast Guard, and the Beykoz facilities support only the local ships. Pendik does not have a logistics facility, except for its own spare part warehouses for the ships at overhauling. After relocating the Taskizak Shipyard operations to the Pendik Shipyard, the workload of the Istanbul Supply Group Command moved to Pendik. Furthermore, the Pendik Shipyard presently has more land than it needs to accomplish shipyard operations and most of the land is idle. Although there are alternative locations for the Kasimpasa logistics supply command, and although the North Naval Sea Area Command has ordered to prepare a preliminary relocation analysis for the current logistics center, neither a complete cost-benefit analysis nor the technical research for the feasibility of the relocation to one of these alternative locations has yet to be accomplished.

The current logistics center cannot improve its service level and cannot capitalize on any technological development. Moreover, a costly restoration to make the logistics center earthquake safe is needed. Consequently restoring the fifty-year-old facilities

instead of building a new one at a better location with the latest technology is not economical.

B. TRANSPORTATION DATA OF THE CURRENT COMMAND

Regarding the mission of the Istanbul Supply Group Command, the transportation schedule does not fluctuate much from year to year, and Turkey's inflation rate is very high and unstable. Therefore, the transportation load values, costs and exchange rate for the year 2000 are used for the calculations. The costs are based on the real constant values for the year 2000, and the exchange rate is 1 US $=620,000 TL (Dec. 2000). The transportation data and the costs are based on the Shipping and Handling Office records of the current logistics center.

The military and the private transportation costs are different. The military transportation cost is about 26,000,000 TL for carrying a 10-ton load 50 km. Similarly, the unit military transportation cost is 52,000 TL/ton-km. The Olkim Transportation Company states the private transportation cost as 250,000,000 TL for carrying a 20-ton load 100 km. Therefore, the unit civilian transportation cost is 125,000TL/ton-km [Ref. 31].

In the following section, the different transportation tasks of the Istanbul Supply Group Command are analyzed.

1. Annual Intercity Military Transportation

For the year 2000, the total transportation load from the current logistics center to other logistics centers in Turkey was about 9,016 tons. Military transportation was used to carry these loads.

FROM	TO	DISTANCE (km)	ANNUAL LOAD (ton)	UNIT COST (TL/ton*km)	TRANSPORTATION COST (TL)
Kasimpasa	Golcuk	157	2,620	52,000	21,389,680,000
Kasimpasa	Ankara	580	943	52,000	28,440,880,000
Kasimpasa	Izmir	566	2,620	52,000	77,111,840,000
Kasimpasa	Aksaz	724	943	52,000	35,502,064,000
Kasimpasa	Erdek	394	315	52,000	6,453,720,000
Kasimpasa	Iskenderun	1,131	630	52,000	37,051,560,000
Kasimpasa	Eregli	674	315	52,000	11,040,120,000
Kasimpasa	Canakkale	320	315	52,000	5,241,600,000
Kasimpasa	Beykoz	47	315	52,000	769,860,000
			TOTAL COST	**TL**	**223,001,324,000**
				$	**359,680**

Table 4.2. Military Transportation Costs from Kasimpasa

2. Annual Military Transportation Costs in Istanbul

As mentioned before, the primary mission of the Istanbul Supply Group Command is to support the Navy Commands and ships in Istanbul. The military support mission transportation costs are presented below:

FROM	TO	DISTANCE (km)	ANNUAL LOAD (ton)	UNIT COST (TL/ton*km)	TRANSPORTATION COST (TL)
Kasimpasa	Kasimpasa	1	2,500	52,000	130,000,000
Kasimpasa	Tuzla	65	2,500	52,000	8,450,000,000
Kasimpasa	Heybeliada	45	2,080	52,000	4,867,200,000
Kasimpasa	Beylerbeyi	25	875	52,000	1,137,500,000
Kasimpasa	Sariyer	24	260	52,000	324,480,000
Kasimpasa	Fenerbahce	33	260	52,000	446,160,000
Kasimpasa	Pendik	50	1,040	52,000	2,704,000,000
			TOTAL COST	**TL**	**18,059,340,000**
				$	**29,130**

Table 4.3. Military Transportation Costs in Istanbul for Current Logistics Center

3. Customs Items Transportation Costs

All Foreign Military Sales (FMS) and international orders for the Navy are shipped to Istanbul customs in Turkey. Orders shipped by sea are delivered to the Haydarpasa Port Customs–on the Asian side–and orders shipped by air are delivered to the Ataturk Airport Customs–on the European side. However, a significant portion of all customs orders is shipped by air. In either case, the Istanbul Supply Group Command is responsible for managing all the customs operations and delivering the customs items to their destinations.

The distance between the current logistics center and Pendik is about 50 km. The Ataturk Airport is 30 km from the existing supply command and, because of the city traffic, it requires almost one hour to transit. Pendik is only 10 km from the Kurtkoy Airport, which is ten to fifteen minutes driving distance. The railroad station is directly across the street from the main gate of the Pendik facilities. If the current logistics center were moved to Pendik, then the Kurtkoy Airport Customs could be used for customs deliveries. This would reduce transportation costs for the Turkish Navy. The following tables show only airport customs savings. Although the Haydarpasa Port Customs is closer to Pendik than Kasimpasa, there is not enough data to calculate these additional savings. Due to regulations, private transportation must be used to deliver the items in the customs office to their destination commands.

FROM	TO	DISTANCE (km)	ANNUAL LOAD (ton)	UNIT COST (TL/ton*km)	TRANSPORTATIO N COST (TL)
Ataturk Airport	Golcuk	187	448	125,000 (P)	10,472,000,000
Ataturk Airport	Cengiz Topel	227	32	125,000 (P)	908,000,000
Ataturk Airport	Pendik	80	103	125,000 (P)	1,030,000,000
P: Transported with Private Vehicles			**TOTAL COST**	**TL**	**12,410,000,000**
M: Transported with Military Vehicles				**$**	**20,015**

Table 4.4. Current Customs Transportation Costs with Private Vehicles

FROM	TO	DISTANCE (km)	ANNUAL LOAD (ton)	UNIT COST (TL/ton*km)	TRANSPORTATIO N COST (TL)
Kurtkoy Airport	Golcuk	102	448	125,000 (P)	5,712,000,000
Kurtkoy Airport	Cengiz Topel	142	32	125,000 (P)	568,000,000
Kurtkoy Airport	Pendik	10	103	52,000 (M)	53,560,000
P: Transported with Private Vehicles			**TOTAL COST**	**TL**	**6,333,560,000**
M: Transported with Military Vehicles				**$**	**10,215**

Table 4.5. Customs Transportation Costs with Private/Military Vehicles for Pendik

The transportation cost comparison is shown below:

	TRANSPORTATION COSTS	
LOCATION	**TL/Year**	**$/Year**
Ataturk Airport (Kasimpasa)	12,410,000,000	20,015
Kurtkoy Airport (Pendik)	6,333,560,000	10,215
SAVINGS	**6,076,440,000**	**9,800**

Table 4.6. Customs Transportation Cost Savings

4. Petroleum Transportation Costs

Military-owned standard 10-ton trucks are used for petroleum transportation. Even though the current logistics center has its own piers, the ships cannot dock at them because of the flooded bridges and the shallowness of the harbor. Almost the entire petroleum demand from this logistics center is for the ships that are in the Pendik Shipyard for overhaul or repair purposes. Therefore, the total transportation cost of the petroleum is calculated as shown below:

FROM	TO	DISTANCE (km)	ANNUAL LOAD (ton)	UNIT COST (TL/ton*km)	TRANSPORTATION COST
Kasimpasa	Pendik	50	1,710	52,000 (M)	**4,446,000,000 TL**
					7,170 $

Table 4.7. Petroleum Transportation Cost

This cost could be completely eliminated if this mission were accomplished at Pendik by pumping the petroleum from the fuel tanks directly to the ships.

5. Other Transportation Costs

Several item groups are managed and acquired only by the logistics center in Golcuk. According to Turkish Navy Acquisition Regulations, these items are managed by only one logistics command to acquire materials by one buyer and in large amounts to gain wholesale price advantages. These items include ship paints, various tools, fire equipment, and preventive maintenance items. However, these items are actually acquired from Istanbul companies and markets; therefore, the contractors increase the price by passing on the extra transportation costs to the buyer that they incur for Golcuk deliveries.

Currently, about 30% of these items are shipped back to the Pendik Shipyard by the Golcuk Supply Center during the year. In the near future, the capacity being used at the Pendik Shipyard is planned to increase significantly.

The current logistics center cannot stock enough paint to meet the demand in Istanbul, and especially the Pendik Shipyard demand. Therefore, all paint is acquired by the Golcuk Supply Center, and then the contractors ship it to Golcuk. However, the Pendik Shipyard demand is periodically shipped from Golcuk back to Pendik throughout the year by military transportation. The total transportation cost for the current situation is calculated in the following table:

FROM	TO	DISTANCE (km)	ANNUAL LOAD (ton)	UNIT COST (TL/ton*km)	TRANSPORTATION COST (TL)
Istanbul	Golcuk	125	6,260	125,000 (P)	97,812,500,000
Golcuk	Pendik	110	1,878	52,000 (M)	10,742,160,000
P: Transported with Private Vehicles M: Transported with Military Vehicles			**TOTAL COST**	**TL**	**108,554,660,000**
				$	**175,090**

Table 4.8. The Transportation Cost for the Current Situation

The cumulative load of all these supplies was about 6,260 tons for the year 2000. As depicted in the table, the total transportation cost for delivering 6,260 tons is about 98 billion TL ($170,090). This extra transportation cost is about 2% of the total procurement cost and the contractor basically adds this to the total contract price for shipping the items from Istanbul to Golcuk. Each year, about 30% (1,878 ton) of these materials are shipped back to Pendik in military vehicles to meet the annual demand. If a new logistics center is built in Istanbul and the acquisition management of these supplies can be delegated to this new center, the extra 2% transportation cost charged by the contractors could be eliminated. Since Golcuk's demand is the 70% of the total supplies acquired, the only transportation cost of the new logistics center in Istanbul would be carrying 70% (4,382 ton) of the total supplies from Istanbul to Golcuk by military transportation. Thus, alternative cost would be as follows:

FROM	TO	DISTANCE (km)	ANNUAL LOAD (ton)	UNIT COST (TL/ton*km)	TRANSPORTATION COST
Istanbul	Golcuk	110	4,382	52,000 (M)	**25,065,040,000 TL**
					$ 40,430

Table 4.9. The Transportation Cost for the Alternative Situation

Building a new logistics center that can stock these extra material groups would save 83,489,620,000 TL ($134,660) compared to the current situation.

6. Transportation Costs Summary

The transportation data and costs of the current logistics center were analyzed for the year 2000. The expected benefits of a new logistics center are not limited to transportation costs. Although numerous benefits exist, this analysis is limited to the transportation costs since adequate data is not available to calculate the additional saving. Furthermore, this type of analysis is beyond the scope of this research.

C. SUMMARY

The Istanbul Supply Group Command has outlived its economic and technologic life at its current location. The maintenance and restoration costs are exceeding the expected benefit levels. The location is no longer suitable to perform its mission. Developing or enlarging the current location is not an option since the area has been

completely surrounded by settlements and connections to the highways are either congested or difficult for trucks to maneuver.

The 1999 earthquake greatly influenced the Turkish Navy's strategy. The earthquake damaged some Navy facilities as well as some logistics centers, including the Istanbul Supply Group Command and some of the shipyards. Therefore, the Turkish Navy began relocating some large bases or re-allocating the workloads. The Pendik Shipyard was acquired as part of these strategic relocation decisions.

This thesis analyzes the benefits of relocating the Istanbul Supply Group Command. There are three alternative locations for a new logistics center in Istanbul other that the current location, and these locations are Sariyer, Beykoz and Pendik. Relocating the current logistics center can significantly reduce the transportation costs and can provide many other benefits. The latest technology in a new logistics center would also reduce operating and personnel expenses. Improving control over the inventories and improving management will save much money.

In the following chapter, the Center of Gravity Method and the Electré Method are used to find the best location to perform the missions of the Istanbul Supply Group Command. Also a model is established in Logical Decisions for Windows (LDW). The results are presented to guide the decision makers to find the best logistics center location to improve customer service and to reduce costs.

V. CASE STUDY: FINDING THE BEST LOGISTICS CENTER LOCATION IN ISTANBUL FOR THE TURKISH NAVY

As stated in the previous chapters, the application of three site selection models will be presented in this chapter to analyze the most advantageous logistics center location in Istanbul for the Turkish Navy. These methods are listed below:

- The Center of Gravity Method
- The Electré Method
- Software Program: Logical Decisions for Windows (LDW)

The analysis and the results are explained in the following sections.

A. THE APPLICATION OF THE CENTER OF GRAVITY METHOD

The Center of Gravity method determines the best location by minimizing transportation costs. The only variable in this method is the distance. There are three different distance calculation methods under the Center of Gravity method. However, only the Rectilinear and Square of Linear Distance methods are applied in this case study since these are more appropriate in warehouse site selection problems.

The data used in this method is the transportation data presented in Chapter IV for the Turkish Navy logistics center in Kasimpasa-Istanbul. The Kasimpasa Logistics Command is the main supply center of the Turkish Navy in Istanbul. This center supports the local navy commands and transports material to other logistics commands in other regions.

1. Rectilinear Distance

Appendix B presents a map of Turkey, which is used to determine the coordinates of all the customer locations. The first step is creating a data table. The coordinates and the transportation data are summarized in Table 5.1.

Location	Coordinates	Load Type	Annual Load (Q_i – Ton)	Cost (C_i – TL/ton*km)
Golcuk	P1 (268,557)	Annual Intercity	2,620	52,000
Golcuk	P1 (268,557)	Customs Items	448	125,000
Ankara	P2 (442,491)	Annual Intercity	943	52,000
Izmir	P3 (102,390)	Annual Intercity	2,620	52,000
Aksaz	P4 (164,269)	Annual Intercity	943	52,000
Erdek	P5 (160,532)	Annual Intercity	315	52,000
Iskenderun	P6 (642,237)	Annual Intercity	630	52,000
Eregli	P7 (366,598)	Annual Intercity	315	52,000
Canakkale	P8 (068,520)	Annual Intercity	315	52,000
Beykoz	P9 (228,594)	Annual Intercity	315	52,000
Cengiz Topel	P10 (283,549)	Customs Items	32	125,000
Kasimpasa	P11 (217,579)	Local	2,500	52,000
Tuzla	P12 (242,560)	Local	2,500	52,000
Heybeliada	P13 (230,570)	Local	2,080	52,000
Beylerbeyi	P14 (225,583)	Local	875	52,000
Sariyer	P15 (224,593)	Local	260	52,000
Fenerbahce	P16 (226,578)	Local	260	52,000
Pendik	P17 (235,571)	Customs Items	103	125,000
Pendik	P17 (235,571)	Petroleum	1,710	52,000
Pendik	P17 (235,571)	Local	1,040	5,200

Table 5.1. The Coordinates and Transportation Data Summary

The following steps are applied in Table 5.2 and Table 5.3. The results are highlighted:

- Sort ascending the abscissa and ordinates of the customer locations,
- Calculate the W_i ($C_i * Q_i$) values,
- Calculate the cumulative sum of W_i values,
- Calculate ($\frac{1}{2} \sum W_i$) value,

Finally, find the number that is equal to the ($\frac{1}{2} \sum W_i$), from the cumulative sum of W_i column. If the ($\frac{1}{2} \sum W_i$) value does not exist in the cumulative sum of W_i column, then find the number that is closest in value to the ($\frac{1}{2} \sum W_i$) but greater than ($\frac{1}{2} \sum W_i$).

The abscissa and ordinate values in these rows give the point T (X; Y), which minimizes the total transportation costs.

ABSCISSA X_0=235					
Location	**X_i**	**C_i(X1000TL)**	**Q_i (Ton)**	**W_i**	**Cumulative Sum of W_i**
Canakkale	68	52	315	16,380	16,380
Izmir	102	52	2,620	136,240	152,620
Erdek	160	52	315	16,380	169,000
Aksaz	164	52	943	49,036	218,036
Kasimpasa	217	52	2,500	130,000	348,036
Sariyer	224	52	260	13,520	361,556
Beylerbeyi	225	52	875	45,500	407,056
Fenerbahce	226	52	260	13,520	420,576
Beykoz	228	52	315	16,380	436,956
Heybeliada	230	52	2,080	108,160	545,116
Pendik	235	125	103	12,875	557,991
Pendik	**235**	52	1,710	88,920	646,911
Pendik	235	52	1,040	54,080	700,991
Tuzla	242	52	2,500	130,000	830,991
Golcuk	268	52	2,620	136,240	967,231
Golcuk	268	125	448	56,000	1,023,231
Cengiz Topel	283	125	32	4,000	1,027,231
Eregli	366	52	315	16,380	1,043,611
Ankara	442	52	943	49,036	1,092,647
Iskenderun	642	52	630	32,760	**1,125,407**
				½ (Σ W_i)	**562,704**

Table 5.2. Calculation of the Best Location's Abscissa Value

The abscissa value of the best location is X (235) on the reference map in Appendix B. The calculation of the best location's ordinate is shown below:

ORDINATE Y_0=560					
Location	**Y_i**	**C_i(X1000TL)**	**Q_i (Ton)**	**W_i**	**Cumulative Sum of W_i**
Iskenderun	237	52	630	32,760	32,760
Aksaz	269	52	943	49,036	81,796
Izmir	390	52	2,620	136,240	218,036
Ankara	491	52	943	49,036	267,072
Canakkale	520	52	315	16,380	283,452
Erdek	532	52	315	16,380	299,832
Cengiz Topel	549	125	32	4,000	303,832
Golcuk	557	52	2,620	136,240	440,072
Golcuk	557	125	448	56,000	496,072
Tuzla	**560**	52	2,500	130,000	626,072
Heybeliada	570	52	2,080	108,160	734,232
Pendik	571	125	103	12,875	747,107
Pendik	571	52	1,710	88,920	836,027
Pendik	571	52	1,040	54,080	890,107
Fenerbahce	578	52	260	13,520	903,627
Kasimpasa	579	52	2,500	130,000	1,033,627
Beylerbeyi	583	52	875	45,500	1,079,127
Sariyer	593	52	260	13,520	1,092,647
Beykoz	594	52	315	16,380	1,109,027
Eregli	598	52	315	16,380	**1,125,407**
				½ ($\sum W_i$)	**562,704**

Table 5.3. Calculation of the Best Location's Ordinate Value

The ordinate value of the best location is Y (560) on the reference map in Appendix B. Therefore, the coordinates of the best location are T (X, Y)= T (235, 560), and the total transportation cost for this point is the minimum. The best point is shown on the following map.

Figure 5.1. The Best Location (Rectilinear) [From Ref. 39]

The best location is on the sea, an unfeasible point; however, the closest feasible locations are Tuzla and Pendik. Pendik is the only alternative location because of the land and installations constraints between the two feasible locations.

2. Square of Linear Distance

Applicable formulas are given in Chapter III. The results of this method are presented in Table 5.4 and Table 5.5. The coordinates of the best point are calculated below:

$X = \sum(W_i*X_i) / \sum W_i = 268,259,821 / 1,125,407 = \mathbf{238.37}$

The ordinate value of the best point is calculated below:

$Y = \sum(W_i*Y_i) / \sum W_i = 585,279,725 / 1,125,407 = \mathbf{520.06}$

Consequently, the coordinates of the best location are T (X, Y)= T (238, 520). The best point is shown on the following map.

Figure 5.2. The Best Location (Square of Linear) [From Ref. 26]

Location	X_i	W_i For Abscissa	W_i*X_i
Canakkale	68	16,380	1,113,840
Izmir	102	136,240	13,896,480
Erdek	160	16,380	2,620,800
Aksaz	164	49,036	8,041,904
Kasimpasa	217	130,000	28,210,000
Sariyer	224	13,520	3,028,480
Beylerbeyi	225	45,500	10,237,500
Fenerbahce	226	13,520	3,055,520
Beykoz	228	16,380	3,734,640
Heybeliada	230	108,160	24,876,800
Pendik	235	12,875	3,025,625
Pendik	235	88,920	20,896,200
Pendik	235	54,080	12,708,800
Tuzla	242	130,000	31,460,000
Golcuk	268	136,240	36,512,320
Golcuk	268	56,000	15,008,000
Cengiz Topel	283	4,000	1,132,000
Eregli	366	16,380	5,995,080
Ankara	442	49,036	21,673,912
Iskenderun	642	32,760	21,031,920
	Σ	**1,125,407**	**268,259,821**

Table 5.4. Abscissa Calculation with Square of Linear Distance

Location	Y_i	W_i For Ordinate	W_i*Y_i
Iskenderun	237	32,760	7,764,120
Aksaz	269	49,036	13,190,684
Izmir	390	136,240	53,133,600
Ankara	491	49,036	24,076,676
Canakkale	520	16,380	8,517,600
Erdek	532	16,380	8,714,160
Cengiz Topel	549	4,000	2,196,000
Golcuk	557	136,240	75,885,680
Golcuk	557	56,000	31,192,000
Tuzla	560	130,000	72,800,000
Heybeliada	570	108,160	61,651,200
Pendik	571	12,875	7,351,625
Pendik	571	88,920	50,773,320
Pendik	571	54,080	30,879,680
Fenerbahce	578	13,520	7,814,560
Kasimpasa	579	130,000	75,270,000
Beylerbeyi	583	45,500	26,526,500
Sariyer	593	13,520	8,017,360
Beykoz	594	16,380	9,729,720
Eregli	598	16,380	9,795,240
		1,125,407	**585,279,725**

Table 5.5. Ordinate Calculation with Square of Linear Distance

Since the logistic center must be inside the city limits of Istanbul and support the local commands, the best location is not a feasible point. However, the closest feasible locations are still on the Asian side of Istanbul, and they are Tuzla and Pendik. Between Pendik and Tuzla, only Pendik is a possible site for the new logistics center because of the land and installations constraints.

B. THE APPLICATION OF THE ELECTRÉ METHOD

The application of the Electré Method to the case study is explained, and the related information about the case study is presented in these following steps.

1. Step 1: Identifying the Options

As stated in Chapter IV, the current logistics center in Istanbul does not suit the changing requirements of the Turkish Navy. This analysis focuses on finding the best location in Istanbul. Based on the Navy owned facilities, lands and commands in Istanbul, there are only four alternative locations where a large logistics center might be built and integrated to the current Navy facilities. These alternatives (options) are listed below and represented by the symbols:

- Kasimpasa (K)
- Sariyer (S)
- Beykoz (B)
- Pendik (P).

2. Step 2: Identifying the Criteria

The preliminary list of criteria was different from the final criteria list. The final list of the criteria was determined after a literature review, interviews and recommendations of the survey participants. The final list of the identified criteria includes 24 issues listed below:

1. Transportation options and opportunities (rail, road, air, sea),
2. Work force availability,
3. Retaining the existing work force of the old center,
4. Attitudes of social environment (i.e., opinions about military installations),
5. Interface opportunities with existing facilities,
6. Proximity to raw material sources, ease of contracting and acquiring costs,
7. Quality of life (neighborhood, fire and police departments, hospitals, public transportation, etc.),
8. Social life, entertainment opportunities, sports, shopping opportunities,
9. Living costs (rent, shopping) compared to wage rates,
10. Proximity to military material demand points/commands (customers),
11. Sewage and garbage service and facilities (for the industrial facilities),

12. Proximity and cooperation of any existing universities and colleges,
13. Existence of high school and elementary schools for employees' children,
14. Topography of the building site (flat, hill, etc.),
15. Access to water,
16. Energy availability (electric, natural gas),
17. Fuel and heating/cooling expenses,
18. Natural safety, natural disaster (flood, earthquake etc.) effects,
19. Crime ratio of the area,
20. Military Confidential information/data/security/military asset protection necessity,
21. Public relations,
22. Customs requirements, proximity of customs offices–seaport, airport etc.–(in this case, Logistic Supply command is responsible for FMS and international orders),
23. Hazardous or dangerous material storage and shipping options (fuel, arms, gas etc.),
24. Enlargement opportunities.

3. Step 3: Weighing the Criteria

A survey (Survey 1) was conducted to accomplish this step of the method. The purpose of this survey was determining the relative importance of each criterion by consulting the expert opinions of the participants. Survey 1 is presented in Appendix C. A total of 25 people (8 Turkish and 17 American) responded to Survey 1. The participants of Survey 1 are categorized and listed below:

- 9 NPS Instructors from the Business School (GSBPP) and Operations Research (OR) curriculums including 2 PhDs, 6 US Military Retired Officers, and 1 Active Duty US Navy Officer (O5),
- 2 US Army Logisticians (O5),
- 6 US Navy Supply Officers (O4)/NPS students,
- 6 Turkish Navy Supply Officers (O2 and O3),
- 1 CEO of a Warehouse Consultancy Company in Turkey,

- 1 Instructor (PhD) from the Istanbul Technical University (ITU).

The survey was evaluated by using SPSS statistics program. The mean of the 25 participants scores to each criterion is assumed as the weight of each criterion. The reliability analysis feature of SPSS is used to justify using the means (average score for each criterion) as the importance level (weight). SPSS calculates the inter-judge reliability of the data sets (scores of participants) and the consistency of the data (correlation among the scores of participants for the same criterion). The results and the scores of participants for Survey 1 are presented in Appendix C. The descriptive statistics and the reliability analysis results of SPSS are also presented in Appendix C.

In the SPSS reliability analysis report, intraclass correlation coefficients, which produce measures of consistency or agreement of values within cases (criteria), are the values that indicate the reliability of the scores provided by different people to the same criterion. The reliability values are as follows:

- Intraclass Correlation Coefficient for all 25 participants

Average Measure Intraclass Correlation = .9388

95.00% C.I.: Lower = .8980 Upper = .9686

Estimated reliability of scale = .8957

Unbiased estimate of reliability = .9082

- Intraclass Correlation Coefficient for only 17 American participants

Average Measure Intraclass Correlation = .9441

95.00% C.I.: Lower = .8971 Upper = .9761

Estimated reliability of scale = .8983

Unbiased estimate of reliability = .9162

- Intraclass Correlation Coefficient for only 8 Turkish participants

Average Measure Intraclass Correlation = .8983

95.00% C.I.: Lower = .7593 Upper = .9757

Estimated reliability of scale = .8228

Unbiased estimate of reliability = .8893

As demonstrated above, all possible reliability values are calculated and are sufficiently high to use the average scores for each criterion as the overall weight.

In this case study, the average score of the total group (25 participants) is used as the weight for each criterion. Consequently, the weights (importance levels) of the criteria are listed below as calculated from the evaluation of Survey 1.

# of CRITERIA	1	2	3	4	5	6	7	8	9	10	11	12
WEIGHT	9.19	6.05	5.42	4.91	6.96	7.38	6.03	4.81	6.16	8.69	7.07	5.47

# of CRITERIA	13	14	15	16	17	18	19	20	21	22	23	24
WEIGHT	6.11	7.2	8.06	8.33	6.89	8.06	6.18	7.62	6.95	7.71	8.49	8.64

Table 5.6. The Weights of the Criteria

4. Step 4 & 5: Determining Scales / Evaluating Options Regarding Criteria

The next step is evaluating the four alternative locations (options) regarding the 24 criteria with the qualitative measures. The qualitative measures used in this case study are "Very good, good, not bad, bad, very bad." A second survey (Survey 2) is conducted to accomplish this option evaluation step. Survey 2 is presented in Appendix D. The participants of this survey are 31 Turkish Navy officers at NPS who have at least 4 to 8 years of living and job experience in Istanbul. After the qualitative measures are obtained, they must be converted to numerical values. The following list shows the values used for converting the qualitative measures to quantitative measures.

- Very Good: 5
- Good : 4
- Not Bad : 3
- Bad : 2
- Very Bad : 1.

All the qualitative measures collected from the 31 participants of the second survey (Survey 2) were converted to quantitative measures using the above numerical values. The converted survey results are listed in Appendix D.

Since there must be only one overall score for each option regarding each criterion, the mean of the 31 scores for each criterion was used as the final score. Another SPSS reliability analysis was performed to justify the internal consistency and

reliability of the converted data before using the average score for calculation purposes. The reliability analysis results were high and satisfactory. The reliability analysis and descriptive statistics reports for each alternative location is presented in Appendix D. The summary of the SPSS reliability analysis is given below:

- Intraclass Correlation Coefficient for Kasimpasa (K)

Average Measure Intraclass Correlation = .8223

95.00% C.I.: Lower = .7179 Upper = .9013

Estimated reliability of scale = .8223

Unbiased estimate of reliability = .8342

- Intraclass Correlation Coefficient for Sariyer (S)

Average Measure Intraclass Correlation = .7730

95.00% C.I.: Lower = .6396 Upper = .8739

Estimated reliability of scale = .7730

Unbiased estimate of reliability = .7881

- Intraclass Correlation Coefficient for Beykoz (B)

Average Measure Intraclass Correlation = .8043

95.00% C.I.: Lower = .6893 Upper = .8913

Estimated reliability of scale = .8043

Unbiased estimate of reliability = .8173

- Intraclass Correlation Coefficient for Pendik (P)

Average Measure Intraclass Correlation = .8216

95.00% C.I.: Lower = .7168 Upper = .9009

Estimated reliability of scale = .8216

Unbiased estimate of reliability = .8335

Finally, the weighted scores are calculated by multiplying the weights of the criteria calculated from evaluating Survey 1 and the average scores of Survey 2. The average scores (Survey 2 results) and the weights of the criteria (Survey 1 results) are listed in Table 5.7. The weighted scores for each alternative location regarding the criteria (multiplication of the score and weight in Table 5.7.) are presented in Table 5.8.

SCORES	ALTERNATIVE LOCATIONS				
# of CRITERIA	K	S	B	P	WEIGHT
1	3.48	3.13	3.03	4.33	9.60
2	4.16	3.39	3.48	4.23	6.24
3	4.19	3.55	3.52	4.16	5.12
4	3.81	3.68	3.39	3.61	4.72
5	3.87	3.45	3.42	4.06	7.00
6	3.45	2.94	3.19	4.16	7.04
7	3.48	4.13	3.35	3.45	5.75
8	3.74	4.35	3.35	2.97	4.44
9	3.13	2.42	3.19	4.00	5.92
10	3.68	3.35	3.71	4.13	8.56
11	3.03	3.16	3.35	3.87	6.54
12	4.00	3.77	2.90	2.87	4.83
13	4.13	3.90	3.61	3.81	5.56
14	2.90	3.39	3.10	4.10	6.76
15	3.58	3.77	3.90	4.10	7.46
16	4.06	3.87	3.77	4.16	7.84
17	3.48	3.29	3.42	3.74	6.32
18	2.45	3.29	3.52	2.68	7.32
19	2.26	3.90	3.55	2.84	5.40
20	3.45	3.74	3.68	3.48	6.88
21	3.65	3.94	3.45	3.35	5.96
22	3.65	3.10	2.97	3.90	7.00
23	2.23	2.58	3.23	3.90	7.68
24	2.03	2.52	3.26	4.26	7.36

Table 5.7. Survey 2 Average Scores and Survey 1 Weight Scores

WEIGHTED SCORES	ALTERNATIVE LOCATIONS			
# of CRITERIA	K	S	B	P
1	33.45	30.04	29.11	41.60
2	39.95	32.52	33.45	40.57
3	40.26	34.06	33.75	39.95
4	36.54	35.30	32.52	34.68
5	37.16	33.14	32.83	39.02
6	33.14	28.18	30.66	39.95
7	33.45	39.68	32.21	33.14
8	35.92	41.81	32.21	28.49
9	30.04	23.23	30.66	38.40
10	35.30	32.21	35.61	39.64
11	29.11	30.35	32.21	37.16
12	38.40	36.23	27.87	27.56
13	39.64	37.47	34.68	36.54
14	27.87	32.52	29.73	39.33
15	34.37	36.23	37.47	39.33
16	39.02	37.16	36.23	39.95
17	33.45	31.59	32.83	35.92
18	23.54	31.59	33.75	25.70
19	21.68	37.47	34.06	27.25
20	33.14	35.92	35.30	33.45
21	34.99	37.78	33.14	32.21
22	34.99	29.73	28.49	37.47
23	21.37	24.77	30.97	37.47
24	19.51	24.15	31.28	40.88

Table 5.8. Weighted Evaluation of Alternatives

If the weights of the criteria are within a range, then these criteria are combined under the same group and the same weight value is assigned to all the criteria of this group in the Electré Method. However, every criterion is assigned to a weight of its own in this case study. The purpose was keeping the sensitivity of the data collected from the Survey 1, and not losing some information by reducing the number of weights.

5. Step 6: Forming the Concordance and Discordance Matrices

The calculation of the concordance matrix is explained in Chapter III. The concordance matrix calculation is presented in Table 5.9 and the final concordance matrix is presented in Table 5.10. For example, the concordance matrix value of "K outranks B " assumption is represented by the "K>=B" column and the calculation algorithm is explained below:

- Compare the values of K and B columns for every criterion,
- Find the values that K>=B, and obtain the weight values of these criteria,
- Record the weights in the K>=B column,
- Find the total of column K>=B and the total of all 24 weights,
- Divide the column total by the total of all weights, and the result is the concordance matrix value of column K and row B.

Weight	P>=B	P>=S	P>=K	B>=P	B>=S	B>=K	S>=P	S>=B	S>=K	K>=P	K>=B	K>=S
9.60	9.60	9.60	9.60					9.60			9.60	9.60
6.24	6.24	6.24	6.24		6.24						6.24	6.24
5.12	5.12	5.12						5.12		5.12	5.12	5.12
4.72	4.72						4.72	4.72		4.72	4.72	4.72
7.00	7.00	7.00	7.00					7.00			7.00	7.00
7.04	7.04	7.04	7.04		7.04						7.04	7.04
5.75	5.75						5.75	5.75	5.75	5.75	5.75	
4.44				4.44			4.44	4.44	4.44	4.44	4.44	
5.92	5.92	5.92	5.92		5.92	5.92						5.92
8.56	8.56	8.56	8.56		8.56	8.56						8.56
6.54	6.54	6.54	6.54		6.54	6.54			6.54			
4.83				4.83			4.83	4.83		4.83	4.83	4.83
5.56	5.56						5.56	5.56		5.56	5.56	5.56
6.76	6.76	6.76	6.76			6.76		6.76	6.76			
7.46	7.46	7.46	7.46		7.46	7.46			7.46			
7.84	7.84	7.84	7.84					7.84			7.84	7.84
6.32	6.32	6.32	6.32		6.32						6.32	6.32
7.32			7.32	7.32	7.32	7.32	7.32		7.32			
5.40			5.40	5.40		5.40	5.40	5.40	5.40			
6.88			6.88	6.88		6.88	6.88	6.88	6.88			
5.96				5.96			5.96	5.96	5.96	5.96	5.96	
7.00	7.00	7.00	7.00					7.00			7.00	7.00
7.68	7.68	7.68	7.68		7.68	7.68			7.68			
7.36	7.36	7.36	7.36		7.36	7.36			7.36			
157.30	122.47	106.44	120.92	34.83	70.44	69.88	50.86	86.86	71.55	36.38	87.42	85.75
Concordance Matrix Values	**0.78**	**0.68**	**0.77**	**0.22**	**0.45**	**0.44**	**0.32**	**0.55**	**0.45**	**0.23**	**0.56**	**0.55**

Table 5.9. Calculation of Concordance Matrix

	K	S	B	P
K	*	0.45	0.44	0.77
S	0.55	*	0.45	0.68
B	0.56	0.55	*	0.78
P	0.23	0.32	0.22	*

Table 5.10. Concordance Matrix

The calculation of the discordance matrix is explained in Chapter III. However a summarized algorithm is presented below for the “K outranks B” assumption:

- Compare the values of K and B columns for every criterion,
- Find the values that K<B and calculate the B-K subtraction,
- Record the subtraction result in the K<B column,
- Find the maximum of column K<B and divide this value by the maximum range value among the scores of all the criteria. The result is the discordance matrix value of the column K and row B.

The discordance matrix calculation is presented in Table 5.11 and the complete first discordance matrix is presented in Table 5.12.

	Range	P<B	P<S	P<K	B<P	B<S	B<K	S<P	S<B	S<K	K<P	K<B	K<S
1	12.49				12.49	0.93	4.34	11.56		3.41	8.15		
2	8.05				7.12		6.50	8.05	0.93	7.43	0.62		
3	6.51			0.31	6.20	0.31	6.51	5.89		6.20			
4	4.02		0.62	1.86	2.16	2.78	4.02			1.24			
5	6.19				6.19	0.31	4.33	5.88		4.02	1.86		
6	11.77				9.29		2.48	11.77	2.48	4.96	6.81		
7	7.47		6.54	0.31	0.93	7.47	1.24						6.23
8	13.32	3.72	13.32	7.43		9.60	3.71						5.89
9	15.17				7.74			15.17	7.43	6.81	8.36	0.62	
10	7.43				4.03			7.43	3.40	3.09	4.34	0.31	
11	8.05				4.95			6.81	1.86		8.05	3.10	1.24
12	10.84	0.31	8.67	10.84		8.36	10.53			2.17			
13	4.96		0.93	3.10	1.86	2.79	4.96			2.17			
14	11.46				9.60	2.79		6.81			11.46	1.86	4.65
15	4.96				1.86			3.10	1.24		4.96	3.10	1.86
16	3.72				3.72	0.93	2.79	2.79		1.86	0.93		
17	4.33				3.09		0.62	4.33	1.24	1.86	2.47		
18	10.21	8.05	5.89						2.16		2.16	10.21	8.05
19	15.79	6.81	10.22			3.41					5.57	12.38	15.79
20	2.78	1.85	2.47			0.62					0.31	2.16	2.78
21	5.57	0.93	5.57	2.78		4.64	1.85						2.79
22	8.98				8.98	1.24	6.50	7.74		5.26	2.48		
23	16.10				6.50			12.70	6.20		16.10	9.60	3.40
24	21.37				9.60			16.73	7.13		21.37	11.77	4.64
	Max. **21.37**	8.05	13.32	10.84	12.49	9.60	10.53	16.73	7.43	7.43	21.37	12.38	15.79
	Discordance Matrix Value	**0.38**	**0.62**	**0.51**	**0.58**	**0.45**	**0.49**	**0.78**	**0.35**	**0.35**	**1.00**	**0.58**	**0.74**

Table 5.11. Calculation of Discordance Matrix

	K	**S**	**B**	**P**
K	*	0.35	0.49	0.51
S	0.74	*	0.45	0.62
B	0.58	0.35	*	0.38
P	1.00	0.78	0.58	*

Table 5.12. First Discordance Matrix

The second discordance matrix (s=2) is calculated in the same manner, but the only difference is using the second greatest deviation between the scores of the compared pair from Table 5.11. The complete second discordance matrix is presented below:

	K	**S**	**B**	**P**
K	*	0.32	0.30	0.35
S	0.38	*	0.39	0.48
B	0.55	0.33	*	0.32
P	0.75	0.71	0.45	*

Table 5.13. Second Discordance Matrix

6. Step 7: Electing and Decision

There are two kinds of thresholds that the decision maker must specify: preference threshold (p) and indifference threshold (q). In this case study, the thresholds are specified as p=0.5 and q=0.6 (notation: 0.5/0.6/1) for the first iteration. For example, the preference relation is defined as follows for the "K outranks B" assumption: If the concordance indicator (value in the concordance matrix) of this option pair is greater than or equal to "p" and the discordance indicator is less than or equal to "q," then K is preferred to B and the corresponding cell will be marked with "*" in the solution figure. The same comparison is performed for all pairs and the results are presented in figures below. The interpretation of the preference figure is explained in Chapter III.

	K	S	B	P
K				*
S				
B	*	*		*
P				

(0.5/0.6/1)

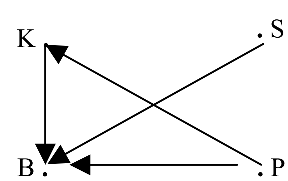

Figure 5.3. First Iteration Results

The possible solutions are S and P options according to the results of the first iteration. The indifference threshold is increased to 0.7 for the second iteration to distinguish between S and P options.

	K	S	B	P
K				*
S				*
B	*	*		*
P				

(0.5/0.7/1)

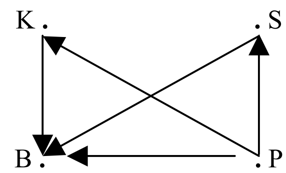

Figure 5.4. Second Iteration Results

Since the only node that has no arrow entering is P, the solution is option P. The second discordance matrix (s=2) is used to control this result at the third iteration. The indifference threshold is chosen as q=0.4 and preference threshold is not changed (p=0.5) (notation: 0.5/0.4/2). The results of the third iteration is shown below:

	K	S	B	P
K				*
S	*			
B		*		*
P				

(0.5/0.4/2)

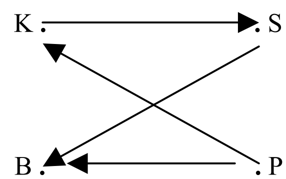

Figure 5.5. Third Iteration Results (Control of the Solution)

The only node that has no arrow entering is, again, P. Therefore, the final solution indicates option P (Pendik). Consequently, the Electré Method recommends Pendik as the best location among the four alternative locations to build a logistics center and military warehouses in Istanbul for the Turkish Navy.

C. THE APPLICATION OF LOGICAL DECISIONS FOR WINDOWS (LDW)

A LDW model is developed using the data collected from surveys. The overall goal is defined as “The Best Logistics Center Location” in LDW. The LDW measures are defined as the 24 criteria used in the Electré Method. The LDW matrix is established with the results of Survey 2 and four alternative locations in this case study. The preference range is established with the least preferred level of 1 and the most preferred level of 5. The following figures show one of the measures in the window and the decision matrix in the LDW model established for this case study.

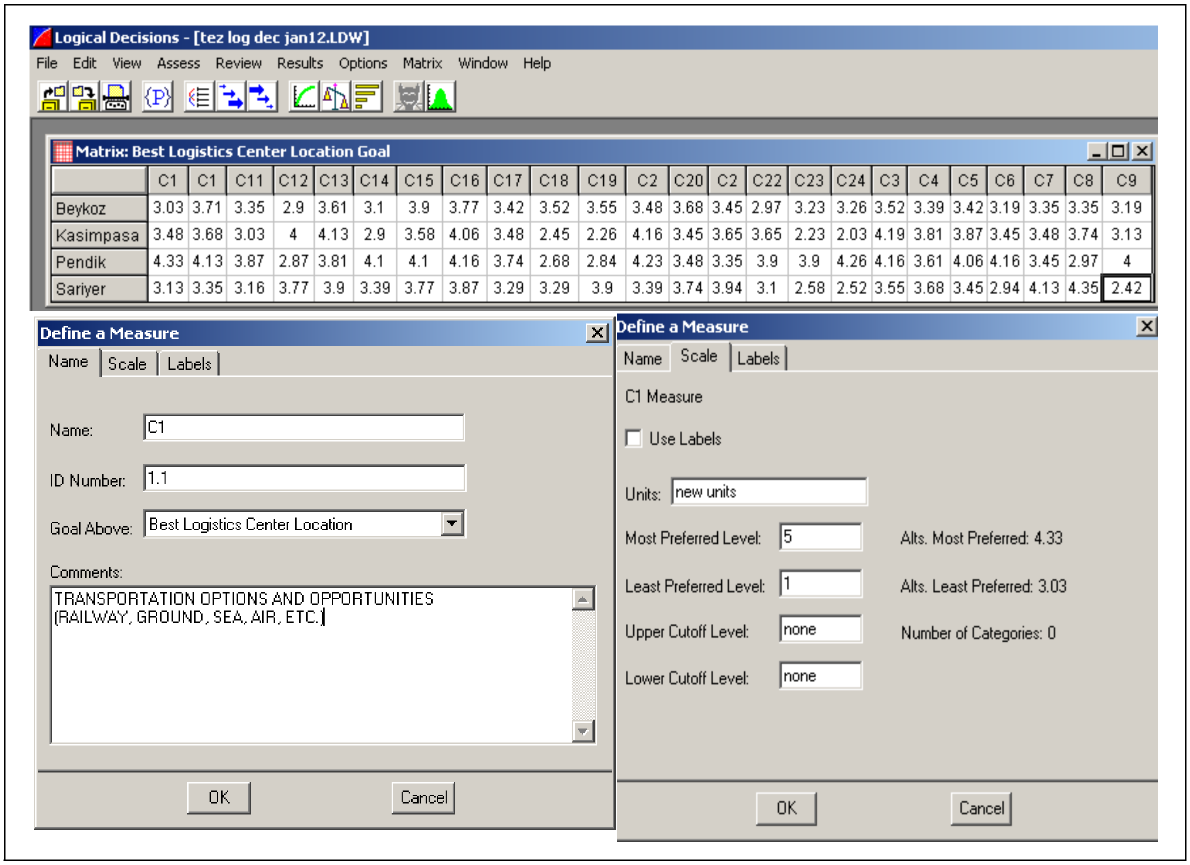

Figure 5.6. LDW Matrix and Measures Windows

"Direct Entry" option is chosen as the weight assessment method in this LDW model. The total of all weights must be 1.0 in this method. Therefore, the weights are calculated as follows from the data of Survey 1 and the percentage of the total weights column values are used as the scaling constant (weight) for the criteria of this case study.

CRITERIA	WEIGHT	% of TOT. WEIGHT
1	9.60	0.06
2	6.24	0.04
3	5.12	0.03
4	4.72	0.03
5	7.00	0.04
6	7.04	0.04
7	5.75	0.04
8	4.44	0.03
9	5.92	0.04
10	8.56	0.05
11	6.54	0.04
12	4.83	0.03
13	5.56	0.04
14	6.76	0.04
15	7.46	0.05
16	7.84	0.05
17	6.32	0.04
18	7.32	0.05
19	5.40	0.03
20	6.88	0.04
21	5.96	0.04
22	7.00	0.04
23	7.68	0.05
24	7.36	0.05
TOTAL	157.30	1.00

Table 5.14. The Direct Entry Method Weights for LDW

Since Pendik receives the highest utility, the LDW solution designates Pendik as the best location among the other alternatives. The LDW ranking solution figures and analysis results are presented below and the alternative comparison graphs for all option pairs are presented in Appendix E:

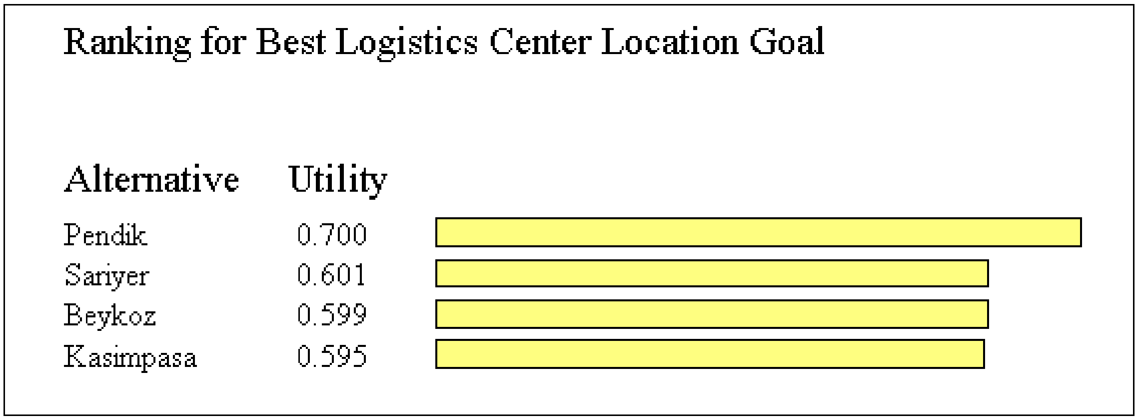

Figure 5.7. LDW Solution: Ranked Alternatives

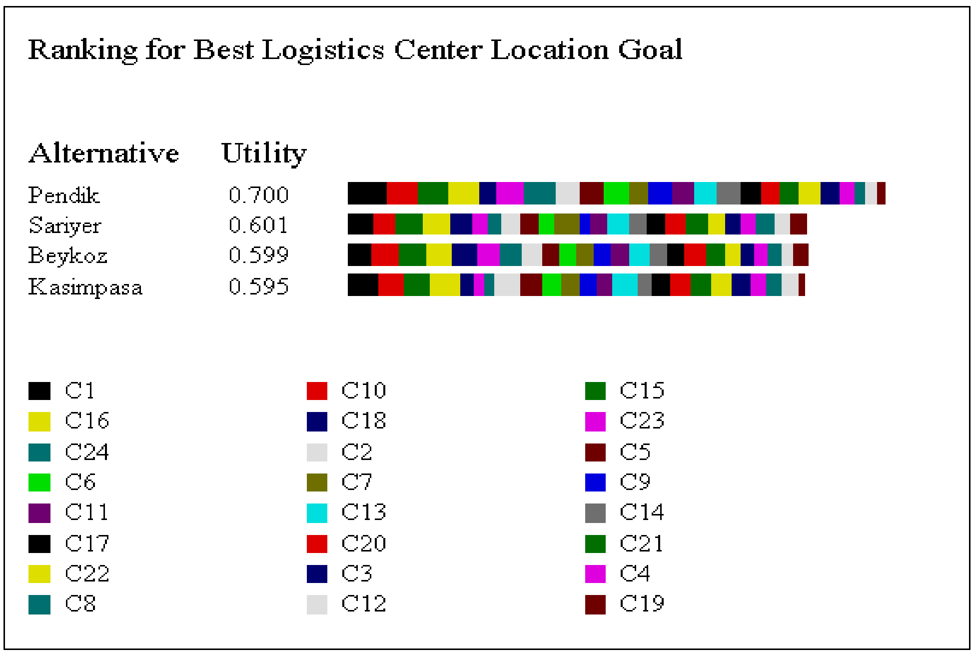

Figure 5.8. LDW Solution: Stacked Bar Ranking

VI. CONCLUSIONS AND RECOMMENDATIONS

A warehouse is a resource and a distribution factory. Organizations must have a warehouse presence in order to succeed in certain demand areas [Ref. 11]. When the existing warehouse facilities cannot satisfy the changing needs of an organization, a new site selection decision must be considered. Naturally, a site selection decision is quite arduous for a logistics manager, since a poor choice for a warehouse is a highly difficult decision to correct [Ref. 2, 3].

The purpose of this research is to determine the best logistics center location for the Turkish Navy in Istanbul so that it can increase the customer service level as well as use the latest technologies in the warehousing industry. The Istanbul Supply Group Command is the main logistics organization of the Turkish Navy in Istanbul. This center is more than 50-year-old and aging problems are developing. Technological obsoleteness and an expanding population and urbanization are some other problems this center is facing. After the 1999 earthquake, the current logistics center required a major and costly restoration. Consequently, the relocation analysis and the best location selection for the Turkish Navy in Istanbul was the case study for this research.

There are various models available for site selection. The Center of Gravity Method, the Electré Method and an LDW model were used in the case study of this thesis. The transportation data and surveys were used to provide the necessary input for these three models and the results were presented.

A. CONCLUSION, RECOMMENDATIONS AND LIMITATIONS

1. Conclusion

The conclusion of the research is based on the assumptions made during the analysis. One of the two main assumptions was about the transportation statistics of the Istanbul Supply Group Command. Since the transportation cost is not the only cost associated with a large logistics center, the Turkish Navy can conduct a further analysis considering the other costs related to a logistics center. The second main assumption was the precision of the survey data collected from the participants. Since the sample size for

both surveys were relatively small, the surveys can be conducted extending the participation and this will increase the precision of the survey data used to make a site selection decision.

a. A Relocation Review is Required for the Istanbul Supply Group Command.

The mission of this logistics center is very dynamic and crucial to the success of the Turkish Navy. Its strategic location is critical in performing its mission. This existing center cannot satisfy the changing needs of the Turkish Navy. The aging problems, technological obsoleteness, and the inability to enlarge the facilities are among the major reasons to consider a relocation project. In fact, the 1999 earthquake significantly damaged the existing facility and this center requires an expensive investment to restore the buildings. The alternative locations must be listed and by using some of the site selection models, an analysis must be made to determine the best location in Istanbul.

2. Recommendations

a. The Turkish Navy should Reevaluate Its Logistical Needs in Istanbul and Consider Relocating Its Existing Logistics Facilities.

Since the world is transforming to a digital environment, organizations use information technology (IT) solutions greatly to achieve their goals. The Turkish Navy must monitor the external environment closely and adapt quickly to compete with the changing requirements. This is imperative because the technology of the Istanbul Supply Group Command is getting obsolete and the facilities are antiquated. The transformation and technological improvements of this center as well as the high operating costs are extremely costly. Therefore, the Turkish Navy should determine its strategic logistical needs to compete with the current technological developments, increase the level of customer service and perform its mission in the most cost effective way.

b. The Turkish Navy should Consider Moving the Istanbul Supply Group Command to Pendik.

Three different site selection models are employed in this thesis to determine the best logistics center location in Istanbul. The first model was based on the Center of Gravity Method and considered only the transportation costs. The Electre Method and the LDW model used the survey results as the input. The research was

conducted by surveying the logistics experts including NPS and Istanbul Technical University (ITU) instructors, U.S. military officers, and Turkish Navy supply officers. The possible selection criteria and alternative locations in Istanbul were analyzed and evaluated by the participants of the surveys. The alternative locations for a new logistics center were Kasimpasa, Sariyer, Beykoz and Pendik. The results of all these models indicated Pendik as the best location for the Turkish Navy.

c. The Turkish Navy should Conduct a Further Analysis Providing Precise Data and Increase the Level of Involvement of the Logistics Personnel.

The insufficiency of available data cannot be overemphasized. The Turkish Navy should rely on the graduate students in foreign countries by providing them with sufficient data for an official relocation project. In addition, increasing the involvement of Turkish Navy logisticians in the project is crucial.

3. Limitations

This analysis is limited to the transportation costs of the current logistics center. Actually, other costs must also be included in a further analysis. Since the data was not available, the transportation costs savings could be underestimated. For example, the transportation costs from other customer locations all over Turkey to the current location were not included in this research. With this additional data, the savings or losses in the transportation costs of the other customers could be calculated more accurately.

4. Topics for Further Research

The following research topics warrant further study:

- The total savings or losses of moving the Istanbul Supply Group Command from Kasimpasa to Pendik. This analysis can include the personnel, process, and overhead savings, etc.
- The analysis of the actual relocation of a warehouse operation. This analysis can include the initial planning, timing of the relocation, the cost of moving, etc.

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APPENDIX A - SITE ANALYSIS CHECKLIST

Ackerman, Kenneth B. [Ref. 3] in his book *Practical Handbook of Warehousing* presents the following Site Analysis Checklist as a useful aid to analyzing location decisions:

General Information

1. Site location (city, county, state):
2. Legal description of the site:
3. Total acreage:

   Approximate cost per acre:

   Approximate dimensions of site:
4. Owner(s) of site (give names and addresses);

Zoning

1. Current: Proposed: Master plan: Anticipated:
2. Is proposed use allowed? ___yes ___no

   Check which, if any, is required: ___rezoning ___variance ___special exception

   Indicate approximate cost:

   Indicate probability of success: ___excellent ___good ___fair ___poor
3. Applicable zoning regulations (attach copy):

   Parking/loading regulations:

   Open space requirements:

   Office portion:

   Maximum number of buildings allowed:

   Warehouse/Distribution Center portion:

   Percent of lot occupancy allowed:

   Height restrictions: Noise limits: Odor limits:

   Are neighboring uses compatible with proposed use? ___yes ___no
4. Can a clear title be secured? ___yes ___no

   Describe easements, protective covenants, or mineral rights, if any:

Topography

1. Grade of slope: Lowest elevation: Highest evaluation:
2. Is site: ___level ___mostly level ___uneven ___steep
3. Drainage ___excellent ___good ___fair ___poor

   Is degrading necessary? ___yes ___no

   Cost of regarding:

5. Are there any ___streams ___brooks ___ditches ___lakes ___ponds ___on site ___bordering site ___adjacent to site?

   Are there seasonal variations? ___yes ___no

5. What is the 100-year flood plan?
6. Is any part of site subject to flooding? ___yes ___no
7. What is the ground water table?
8. Describe surface soil:
9. Does site have any fill? ___yes ___no
10. Soil percolation rate ___excellent ___good ___fair ___poor
11. Load-bearing capacity of soil: ___PSF
12. How much of site is wooded: How much to be cleared:

    Restrictions on tree removal: Cost of clearing site:

Existing Improvements

1. Describe existing improvements.
2. Indicate whether to be ___left as is ___remodeled ___renovated ___moved ___demolished

Landscaping Requirements

1. Describe the landscaping requirements for building parking lots, access road, loading zones, and buffer if necessary.

Access to Site

1. Describe existing highways and access roads, including distance to site (include height and weight limits of bridges and tunnels, if any).
2. Is site visible from highway? ___yes ___no
3. Describe access including distance from site to
   - Interstate highways
   - Major local roads
   - Central business district
   - Rail
   - Water
   - Airport.

   Describe availability of public transport?
4. Will an access road be built? ___yes ___no

   If yes, who will build it? Who will maintain it? Cost?

   Indicate curb cuts, median cuts, traffic signals, and turn limitations:
5. Is rail extended to site? ___yes ___no If yes, name of railroad(s):

   If no, how far? Cost of extension to site:

   Who will maintain it? Is abandonment anticipated? ___yes ___no

Storm Drainage

1. Location and size of existing storm sewers:
2. Is connection to them possible? ___yes ___no Tap charges:

3. Where can storm waters be discharged?
4. Where can roof drainage be discharged?
5. Describe anticipated or possible long-range plans for permanent disposal of storm waters, including projected cost to company.

Sanitary Sewage

1. Is public treatment available? ___yes ___no. If no, what are the alternatives?
2. Is there sanitary sewage to site? ___yes ___no. Location of sewer mains:
3. Cost of materials (from building to main)–include surface restoration if necessary:
4. Tap charges:
5. Special requirements (describe fully);
6. Describe possible or anticipated long-range plans for permanent disposal of sewage, including projected cost to company.

Water

1. Is there a water line to site? ___yes ___no
2. Location of main: Size of main:
3. Water pressure: Pressure variation:
4. Hardness of water:
5. Source of water supply: Is supply adequate? ___yes ___no
6. Capacity of water plant: Peak demand:
7. Who furnishes water meters? Is master meter required? ___yes ___no

   Preferred location of meters: ___outside ___inside
8. Are fire hydrants metered? ___yes ___no
9. Attach copy of meter rates, including sample bill for anticipated demand if possible.

Electric Power

1. Is adequate electric power available to site? ___yes ___no

   Capacity available at site:

2. Describe high voltage lines at site:
3. Type of service available:
4. Service is ___underground ___overhead
5. Reliability of system ___excellent ___good ___fair ___poor
6. Metering is ___indoor ___outdoor
7. Is sub-metering permitted? ___yes ___no
8. Indicate if reduced rates are available for
   - Heat pumps: ___yes ___no
   - Electric heating: ___yes ___no
9. Attach copy of rates, including sample bill for anticipated demand, if possible.

Fuel

1. Type of gas available:
2. Location of existing gas lines in relation to site:
3. Existence of a refinery:

Taxes

1. Date of most recent appraisal:
2. Real estate tax rate history:
3. History of tax assessments:
4. Proposed increases:
5. Are there any abatement programs in effect? ___yes ___no If yes, describe.
6. Is site in an Enterprise Zone? ___yes ___no

7. Duty free zone? __yes ___no

8. Indicate anticipated or possible major public improvements:

9. Services provided for taxes paid: Local: County: State:

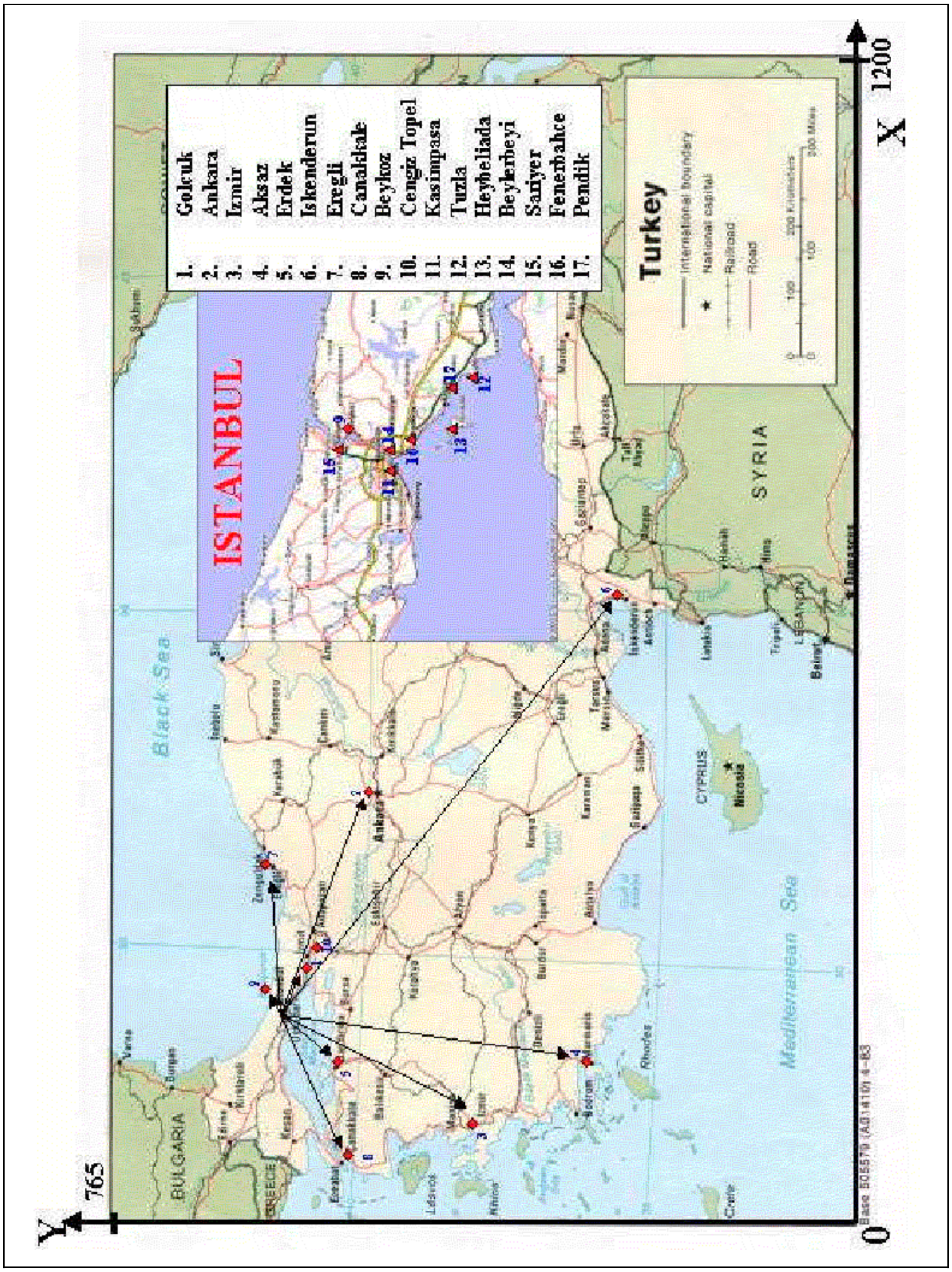
10. What is state policy on inventory tax?

11. Indicate rates for:

    - Personal income tax,
    - Corporate income tax,
    - Payroll tax,
    - Unemployment compensation,
    - Personal property tax,
    - Sales and use tax,
    - Franchise tax,
    - Other taxes.

APPENDIX B - CUSTOMER & TRANSPORTATION LOCATIONS

Customer points of the current logistics center in Istanbul are shown on the following map of Turkey [Ref 26, 39].



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APPENDIX C - THESIS SURVEY 1

A. A COPY OF THE SURVEY 1

I am conducting a research to find the best warehouse and logistics center site in Istanbul for the Turkish Navy. This logistics center will be used for stocking various military items needed by customer commands. These items include spare parts, petroleum, stationary, health products, appliances, and clothing.

This survey is a part of my thesis, which requires me to apply the Electré Method for determining the best location. The following is the list of some criteria for choosing a military warehouse location.

Please weigh each of the following criteria with a score from 1 to 10 by considering their importance levels according to the purpose mentioned above. The results of this survey will be used as objective and expert data for applying the Electré Method in my thesis. Thanks for your help and cooperation.

Ugur Erdemir

SURVEY 1 QUESTIONS

Assume that there are alternative locations that you can choose for building a military logistics center / warehouses and you are considering the following criteria to decide among alternatives. Please rank the criteria for their importance levels based upon your knowledge and experience.

1 =lowest importance   10=highest importance

NO.	CRITERIA	WEIGHT (1…10)
1	Transportation options and opportunities (rail, road, air, sea)	
2	Work force availability	
3	Retaining the existing work force	
4	Attitudes of social environment (i.e., opinions about military installations)	
5	Interface opportunities with existing facilities	
6	Proximity to raw material sources, ease of contracting and acquiring costs	
7	Quality of life (neighborhood, fire and police departments, hospitals, public transportation, etc.)	
8	Social life, entertainment opportunities, sports, shopping opportunities	
9	Living costs (rent, shopping) compared to wage rates	
10	Proximity to military material demand points/commands (customers)	
11	Sewage and garbage service and facilities	
12	Proximity and cooperation of any existing universities and colleges	
13	Existence of high school and elementary schools for employees' children	
14	Topography of the building site (flat, hill, etc.)	
15	Access to water	
16	Energy availability (electric, natural gas)	
17	Fuel and heating/cooling expenses	
18	Natural safety, natural disaster (flood, earthquake etc.) effects	
19	Crime ratio of the area	
20	Military Confidential information/data/security/military asset protection necessity	
21	Public relations	
22	Customs requirements, proximity of customs offices – seaport, airport etc.–(in our case, Logistic Supply command is responsible for FMS and international orders)	
23	Hazardous or dangerous material storage and shipping options (fuel, arms, gas etc.)	
24	Enlargement opportunities	

Please provide any additional comments that you may have. If you believe that any of the above criteria should not be included or if there are others you believe are critical, please include those in your comments. ____________________________________

____

____

Thanks for your help and response.

B. SURVEY 1 RESULTS: 25 PARTICIPANTS & THEIR SCORES

SCORES	PARTICIPANTS																									
CRITERIA	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**MEAN**
1	10	10	10	10	10	10	10	7	10	10	9	10	9	9	10	9	10	10	10	9	10	10	10	9	9	9.60
2	5	6	8	7	6	9	8	7	6	7	7	7	5	7	6	6	2	8	7	5	7	3	8	6	3	6.24
3	2	2	2	4	3	4	5	8	6	7	6	5	5	6	7	4	2	6	6	8	7	2	9	5	7	5.12
4	3	4	2	3	2	4	7	5	3	6	5	3	6	6	8	4	1	4	5	6	9	1	8	6	7	4.72
5	5	7	8	8	7	4	9	7	8	8	5	6	6	8	9	6	5	7	7	7	6	9	8	7	8	7.00
6	2	4	6	7	5	5	9	4	4	9	7	7	8	7	10	7	6	10	10	9	10	10	7	8	5	7.04
7	3	6	3	3	3	6	9	7	3	7	5	6	7	7	6	8	5	5	6	5	9		7	6	6	5.75
8	3	3	2	2	2	3	8	6	2	7	3	6	6	6	6	6	5	2	4	5	7	2	5	4	6	4.44
9	3	7	5	5	4	4	9	7	5	8	5	4	6	7	8	7	5	9	5	6	8	3	7	5	6	5.92
10	10	4	10	10	10	8	7	8	8	10	8	8	9	9	10	8	5	10	9	8	10	8	10	10	7	8.56
11	3	2	7	8	5	6	8	6	4	9	5	6	6	7	10	8	9	7	7	7	8		8	8	3	6.54
12	3	1	3	3	5	3	8	6	3	6	3	2	5	4	6	7	3	5	8	8	5		8	6	5	4.83
13	3	5	3	3	3	3	9	7	6	7	6	4	6	4	6	8	4	6	7	8	8	3	7	7	6	5.56
14	4	8	5	5	6	3	8	7	7	9	5	7	6	6	8	9	6	6	10	9	8	4	7	8	8	6.76
15	3	7	6	7	6	7	10	8	4	9	8	6	8	6	10	8	10	4	8	9	9		8	8	10	7.46
16	4	9	7	7	7	7	10	8	4	10	7	6	7	6	10	10	10	7	10	9	10	6	8	8	9	7.84
17	5	6	5	6	4	4	9	7	4	8	4	6	7	5	8	7	5	7	7	7	10	6	7	8	6	6.32
18	4	8	3	3	4	6	9	8	10	10	7	4	7	4	10	9	5	10	10	10	10	6	10	9	7	7.32
19	3	5	3	3	2	4	8	6	6	9	5	4	7	7	9	5	5	6	8	5	6	2	9	7	1	5.40
20	3	8	5	5	3	4	6	7	5	7	6	4	7	8	10	8	9	10	10	8	10	4	8	10	7	6.88
21	3	2	5	6	5	4	7	6	3	8	4	5	7	6	9	8	6	5	8	7	10		8	7	4	5.96
22	4	9	6	8	7	3	8	6	2	10	4	7	8	7	10	9	9	4	10	7	10	9	6	8	4	7.00
23	6	8	5	5	6	7	8	6	10	10	6	7	8	6	10	9	9	8	10	6	10	7	7	10	8	7.68
24						4	9	7				7	7	7	10	8	8				7			7		7.36
* The empty cells are the missing values that the participants did not fill.																										

C. SPSS REPORTS & SURVEY 1 EVALUATION

1. Descriptive Statistics

	N	Range	Minimum	Maximum	Mean		Std. Deviation	Variance
CRITERIA	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic
C01	25	3.00	7.00	10.00	9.6000	.1414	.7071	.500
C02	25	7.00	2.00	9.00	6.2400	.3380	1.6902	2.857
C03	25	7.00	2.00	9.00	5.1200	.4216	2.1079	4.443
C04	25	8.00	1.00	9.00	4.7200	.4379	2.1894	4.793
C05	25	5.00	4.00	9.00	7.0000	.2708	1.3540	1.833
C06	25	8.00	2.00	10.00	7.0400	.4564	2.2818	5.207
C07	24	6.00	3.00	9.00	5.7500	.3674	1.7998	3.239
C08	25	6.00	2.00	8.00	4.4400	.3833	1.9166	3.673
C09	25	6.00	3.00	9.00	5.9200	.3460	1.7301	2.993
C10	25	6.00	4.00	10.00	8.5600	.3219	1.6093	2.590
C11	24	8.00	2.00	10.00	6.5417	.4169	2.0426	4.172
C12	24	7.00	1.00	8.00	4.8333	.4199	2.0572	4.232
C13	25	6.00	3.00	9.00	5.5600	.3833	1.9166	3.673
C14	25	7.00	3.00	10.00	6.7600	.3572	1.7861	3.190
C15	24	7.00	3.00	10.00	7.4583	.3992	1.9556	3.824
C16	25	6.00	4.00	10.00	7.8400	.3682	1.8412	3.390
C17	25	6.00	4.00	10.00	6.3200	.3200	1.6000	2.560
C18	25	7.00	3.00	10.00	7.3200	.5122	2.5612	6.560
C19	25	8.00	1.00	9.00	5.4000	.4583	2.2913	5.250
C20	25	7.00	3.00	10.00	6.8800	.4594	2.2971	5.277
C21	24	8.00	2.00	10.00	5.9583	.4148	2.0319	4.129
C22	25	8.00	2.00	10.00	7.0000	.4761	2.3805	5.667
C23	25	5.00	5.00	10.00	7.6800	.3402	1.7010	2.893
C24	11	6.00	4.00	10.00	7.3636	.4527	1.5015	2.255

2. Reliability Analysis: Scale (Parallel)

a. Report for the Total Group of 25 Participants

- **Intraclass Correlation Coefficient**

Two-Way Mixed Effect Model (Consistency Definition):

People Effect Random, Measure Effect Fixed

Average Measure Intraclass Correlation = .9388

95.00% C.I.: Lower = .8980 Upper = .9686

- **Parameter Estimates**

Estimated common mean = 6.5544

Estimated common variance = 5.1192

Error variance = 3.6816

True variance = 1.4376

Estimated reliability of scale = **.8957**

Unbiased estimate of reliability = **.9082**

b. Report for the 17 American Participants

- **S C A L E (P A R A L L E L)**

		Mean	Std. Dev.	Cases
1.	CRITERION01	9.5882	.7952	17.0
2.	CRITERION02	6.4118	1.5435	17.0
3.	CRITERION03	4.5882	1.9384	17.0
4.	CRITERION04	4.2353	1.9212	17.0
5.	CRITERION05	6.8235	1.5098	17.0
6.	CRITERION06	6.2941	2.1144	17.0
7.	CRITERION07	5.5294	1.9403	17.0
8.	CRITERION08	4.4706	2.0346	17.0
9.	CRITERION09	5.8235	1.7042	17.0
10.	CRITERION10	8.3529	1.7657	17.0
11.	CRITERION11	6.4118	2.1811	17.0
12.	CRITERION12	4.1765	1.9117	17.0
13.	CRITERION13	5.1176	1.9327	17.0
14.	CRITERION14	6.4118	1.6977	17.0
15.	CRITERION15	7.2353	1.9852	17.0
16.	CRITERION16	7.5882	2.0018	17.0
17.	CRITERION17	5.8824	1.5765	17.0
18.	CRITERION18	6.5294	2.5768	17.0
19.	CRITERION19	5.3529	2.1196	17.0
20.	CRITERION20	6.1765	2.0687	17.0
21.	CRITERION21	5.5294	1.9403	17.0
22.	CRITERION22	6.8824	2.4208	17.0
23.	CRITERION23	7.4118	1.7342	17.0
24.	CRITERION24	7.4064	1.1792	17.0
	N of Cases =	17.0		

- **Intraclass Correlation Coefficient**

Two-Way Mixed Effect Model (Consistency Definition):

People Effect Random, Measure Effect Fixed

Average Measure Intraclass Correlation = .9441

95.00% C.I.: Lower = .2665 Upper = .6297

- **Parameter Estimates**

Estimated common mean = 6.2596

Estimated common variance = 5.2363

Error variance = 3.7042

True variance = 1.5321

Estimated reliability of scale = **.8983**

Unbiased estimate of reliability = **.9162**

c. Report for the 8 Turkish Participants

- **S C A L E (P A R A L L E L)**

		Mean	Std. Dev.	Cases
1.	CRITERION01	9.6250	.5175	8.0
2.	CRITERION02	5.8750	2.0310	8.0
3.	CRITERION03	6.2500	2.1213	8.0
4.	CRITERION04	5.7500	2.4928	8.0
5.	CRITERION05	7.3750	.9161	8.0
6.	CRITERION06	8.6250	1.8468	8.0
7.	CRITERION07	6.2188	1.2917	8.0
8.	CRITERION08	4.3750	1.7678	8.0
9.	CRITERION09	6.1250	1.8851	8.0
10.	CRITERION10	9.0000	1.1952	8.0
11.	CRITERION11	6.8177	1.6451	8.0
12.	CRITERION12	6.2292	1.5091	8.0
13.	CRITERION13	6.5000	1.6036	8.0
14.	CRITERION14	7.5000	1.8516	8.0
15.	CRITERION15	7.9323	1.7831	8.0
16.	CRITERION16	8.3750	1.4079	8.0
17.	CRITERION17	7.2500	1.2817	8.0
18.	CRITERION18	9.0000	1.6036	8.0
19.	CRITERION19	5.5000	2.7775	8.0
20.	CRITERION20	8.3750	2.1339	8.0
21.	CRITERION21	6.8698	1.8879	8.0
22.	CRITERION22	7.2500	2.4349	8.0
23.	CRITERION23	8.2500	1.5811	8.0
24.	CRITERION24	7.2727	.1683	8.0

- **Intraclass Correlation Coefficient**

Two-Way Mixed Effect Model (Consistency Definition):

People Effect Random, Measure Effect Fixed

Average Measure Intraclass Correlation = .8983

95.00% C.I.: Lower = .7593 Upper = .9757

- **Parameter Estimates**

Estimated common mean = 7.1809

Estimated common variance = 4.6722

Error variance = 3.6337

True variance = 1.0385

Estimated reliability of scale = **.8228**

Unbiased estimate of reliability = **.8893**

APPENDIX D - THESIS SURVEY 2

A. A COPY OF THE SURVEY 2

I am conducting a research to find the best warehouse and logistics center site in Istanbul for the Turkish Navy. This logistics center will be used for stocking various military items needed by customer commands. These items include spare parts, petroleum, stationary, health products, appliances, and clothing.

This survey is a part of my thesis for which I must apply the Electré Method for determining the best location. The following is the list of the criteria and four alternative locations for choosing a military warehouse location in Istanbul.

Please evaluate the locations regarding the criteria with one of the following evaluation measures (VERY GOOD, GOOD, NOT BAD, BAD, VERY BAD). As a Turkish Navy officer, you all know that a Supply Group Command is still in service at Kasimpasa-Istanbul. Beykoz and Sariyer are two other alternative locations with existing naval facilities, which vary in size. The last alternative location is Pendik, another existing naval facility, which was established after the 1999 earthquake. The Turkish Navy owns a shipyard at Pendik.

The results of this survey will be used as objective and expert data for applying the Electre Method in my thesis. Thanks for your help and cooperation.

Ugur Erdemir

SURVEY 2 QUESTIONS

Assume that there are alternative locations that you can choose for building a military logistics center / warehouses and you are considering the following criteria to decide among alternatives. Please rank the criteria for their importance levels based upon your knowledge and experience.

VERY GOOD/GOOD/NOT BAD/BAD/ VERY BAD

NO.	CRITERIA	K.pasa	Sariyer	Beykoz	Pendik
1	Transportation options and opportunities (rail, road, air, sea)				
2	Work force availability				
3	Retaining the existing work force				
4	Behaviors of social environment (i.e., opinions about military installations)				
5	Interface opportunities with existing facilities				
6	Proximity to raw material sources, ease of contracting and acquiring costs				
7	Quality of life (neighborhood, fire and police departments, hospitals, public transportation, etc.)				
8	Social life, entertainment opportunities, sports, shopping opportunities				
9	Living costs (rent, shopping) compared to wage rates				
10	Proximity to military material demand points/commands (customers)				
11	Sewage and garbage service and facilities				
12	Proximity and cooperation of any existing universities and colleges				
13	Existence of high school and elementary schools for employees' children				
14	Topography of the building site (flat, hill, etc.)				
15	Access to water				
16	Energy availability (electric, natural gas)				
17	Fuel and heating/cooling expenses				
18	Natural safety, natural disaster (flood, earthquake etc.) effects				
19	Crime ratio of the area				
20	Military Confidential information/data/security/military asset protection necessity				
21	Public relations				
22	Customs requirements, proximity of customs offices–seaport, airport etc. (in our case, Logistic Supply command is responsible for FMS and international orders)				
23	Hazardous or dangerous material storage and shipping options (fuel, arms, gas etc.)				
24	Enlargement opportunities				

Please provide any additional comments that you may have. ________________________

____

B. SURVEY 2 RESULTS: UNWEIGHTED NUMERICAL SCORES

1. Alternative Location: Kasimpasa

Score	PARTICIPANTS																													
NO	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**
1	2	4	4	3	4	2	5	5	4	5	2	3	4	3	4	3	4	3	4	3	4	3	4	4	5	4	4	4	1	2	2
2	4	5	5	3	4	4	4	5	4	4	4	4	5	4	4	4	4	4	4	5	5	5	4	4	4	4	5	4	2	4	4
3	2	5	5	4	4	4	4	4	4	5	4	4	4	3	4	4	4	4	5	5	5	5	5	5	4	4	5	5	2	4	4
4	4	3	4	4	2	4	4	5	4	5	4	4	4	4	4	4	4	4	4	2	5	4	3	4	2	4	5	4	4	2	4
5	4	5	4	5	4	4	4	4	4	5	3	3	4	4	4	4	3	3	3	4	5	4	4	4	2	3	4	4	4	4	4
6	4	4	5	4	4	2	3	3	5	5	4	2	4	4	4	3	4	3	4	2	5	3	3	4	4	2	4	3	2	2	2
7	5	4	4	3	4	4	4	3	4	4	3	4	3	1	2	4	2	3	5	2	5	3	4	3	1	5	5	5	4	3	2
8	5	4	3	2	4	2	5	4	5	5	3	4	5	4	4	3	4	3	5	2	4	4	4	2	2	5	5	5	4	2	3
9	2	3	3	3	4	4	2	2	3	4	4	3	5	4	2	4	4	2	2	3	3	3	3	4	4	2	4	4	1	2	4
10	3	3	4	3	4	4	4	4	4	4	3	3	4	4	2	3	4	4	4	2	4	5	4	4	4	4	5	4	1	5	4
11	2	3	2	3	3	2	4	1	4	4	3	2	3	2	2	4	2	4	3	2	4	3	4	3	4	4	5	3	4	2	3
12	4	4	5	4	4	4	4	5	5	4	4	4	5	1	4	4	4	4	5	4	5	4	3	2	4	4	5	5	1	5	4
13	4	4	4	4	4	4	4	5	5	4	4	5	5	3	4	4	4	4	4	4	3	4	4	4	4	4	5	5	4	4	4
14	4	2	4	1	4	2	4	1	3	4	1	3	2	1	2	4	2	2	4	4	4	3	4	4	5	2	5	3	2	1	3
15	3	3	4	2	2	2	4	5	3	5	4	3	5	5	2	4	4	4	4	2	4	3	4	4	4	4	5	3	4	2	4
16	4	3	4	3	3	3	4	5	5	4	4	4	5	3	4	5	4	4	4	4	5	4	4	5	4	4	5	4	4	4	4
17	3	3	3	2	3	4	4	5	4	5	3	4	4	4	2	4	4	2	3	4	4	3	3	4	4	4	3	4	4	1	4
18	2	3	2	1	2	2	2	1	3	4	1	4	3	3	2	3	4	2	2	3	2	3	2	3	3	2	3	3	2	2	2
19	2	3	3	1	1	4	2	1	3	3	2	2	3	1	2	4	2	2	1	2	2	4	2	1	2	2	3	3	1	1	5
20	2	4	2	2	2	4	4	2	3	4	5	3	3	5	2	3	4	4	5	2	3	5	4	3	2	4	5	4	4	4	4
21	4	4	4	3	3	3	4	3	4	4	4	4	4	4	4	3	3	4	5	4	4	4	4	2	1	4	5	5	4	2	3
22	4	4	5	2	3	3	3	5	4	5	4	4	4	1	5	2	3	5	5	5	4	4	3	4	4	4	4	4	1	3	2
23	4	1	1	3	2	2	2	1	3	3	1	2	3	2	1	2	2	2	2	2	2	3	3	4	3	2	3	3	1	1	3
24	2	1	1	3	2	2	2	1	2	4	1	2	3	3	1	2	1	2	1	2	2	2	3	4	4	1	3	2	1	1	2

2. Alternative Location: Sariyer

Score	PARTICIPANTS																													
NO	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**
1	2	3	2	2	3	3	4	3	3	4	1	3	4	5	4	4	3	3	3	3	3	5	3	4	2	2	4	3	2	4	3
2	2	2	3	2	2	4	4	3	4	3	4	3	4	4	4	3	2	4	3	4	2	5	4	4	3	3	4	3	5	4	4
3	2	2	4	2	2	5	4	3	3	4	4	4	4	4	4	3	2	4	4	4	4	5	3	3	3	3	4	4	5	4	4
4	2	3	4	2	4	4	3	2	3	5	4	4	5	3	2	4	3	5	4	4	4	4	3	5	5	4	4	4	4	4	3
5	4	2	4	2	3	4	4	5	3	5	4	3	4	5	2	2	3	4	3	3	3	4	4	3	4	2	4	3	4	4	3
6	4	3	4	2	2	3	3	4	3	3	2	2	5	3	2	4	4	3	3	2	3	3	3	2	2	2	4	3	2	4	2
7	4	5	V	4	5	3	4	5	4	3	4	3	5	4	4	4	3	5	3	5	4	4	4	5	4	4	5	4	4	4	5
8	4	5	3	5	5	5	5	5	3	5	4	4	5	4	5	4	4	5	4	5	5	5	3	5	4	4	4	5	2	4	5
9	2	2	3	2	2	2	2	1	2	3	2	2	3	4	2	2	3	2	2	2	2	2	2	2	2	2	4	3	4	2	5
10	4	3	3	2	3	4	3	2	3	3	4	3	4	3	4	4	4	4	4	2	4	3	4	3	3	3	4	3	4	4	3
11	2	3	2	2	2	3	4	1	4	3	3	2	3	4	4	4	2	4	3	2	4	3	3	3	4	4	4	4	4	4	4
12	4	4	5	5	4	3	4	5	4	3	4	2	5	4	4	4	3	4	2	4	4	4	3	4	4	4	4	4	1	4	4
13	4	4	4	5	3	4	4	4	4	3	3	4	5	3	4	4	4	4	2	4	3	4	4	4	4	4	4	5	4	5	4
14	3	3	4	4	3	4	4	1	3	3	2	5	5	5	2	3	2	4	3	3	3	3	3	4	3	3	4	3	4	4	5
15	3	3	4	3	3	4	4	5	3	5	3	3	5	4	2	4	4	4	4	2	4	4	4	4	4	4	5	4	4	4	4
16	4	3	4	2	3	4	4	3	5	3	4	4	5	4	4	5	4	4	4	4	4	5	3	3	4	4	5	3	4	4	4
17	3	3	3	3	3	3	4	5	4	3	3	2	5	4	2	3	3	2	3	4	3	3	3	4	3	4	3	4	4	2	4
18	2	3	4	5	2	3	2	1	4	5	2	4	5	1	2	5	5	3	4	4	2	4	2	3	2	4	3	5	2	4	5
19	4	4	3	5	4	4	2	4	4	4	4	4	5	4	4	4	4	3	3	4	4	5	3	5	4	3	4	5	4	4	3
20	2	4	2	5	4	4	4	4	3	5	4	4	5	5	4	3	3	2	4	3	3	3	4	3	4	4	4	5	4	4	4
21	4	4	4	5	4	4	4	3	4	4	4	4	4	4	4	3	3	4	3	4	4	5	4	4	4	4	5	5	2	4	4
22	4	3	3	4	3	2	3	2	3	3	2	4	4	2	2	4	3	4	3	4	4	4	3	1	1	2	4	3	4	4	4
23	4	1	1	2	1	4	2	2	3	4	3	2	4	3	2	2	4	2	2	2	3	2	3	2	2	2	4	4	1	3	4
24	2	2	1	1	1	3	2	2	2	4	2	4	5	3	2	3	2	3	1	2	5	3	2	2	2	2	3	3	1	4	4

3. Alternative Location: Beykoz

Score	PARTICIPANTS																													
NO	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**
1	4	3	2	4	3	3	2	2	3	4	1	3	3	5	2	5	4	3	3	3	3	5	3	3	2	2	4	3	1	3	3
2	4	3	3	4	2	4	5	2	4	3	4	3	3	5	4	5	2	4	2	3	2	5	4	3	3	3	4	4	4	3	4
3	4	2	4	3	2	5	4	2	4	4	4	4	4	4	4	4	2	4	4	3	4	5	3	3	3	3	4	2	4	3	4
4	2	3	4	3	2	4	2	3	4	4	4	3	4	4	4	3	3	4	3	5	4	5	3	3	4	4	4	4	1	2	3
5	4	3	4	3	3	4	5	3	4	4	4	3	4	4	2	4	3	3	4	4	3	4	4	4	2	2	3	3	1	4	4
6	3	3	4	3	2	3	4	5	3	4	2	3	3	4	2	4	4	3	3	2	3	4	3	2	2	3	4	4	4	4	2
7	4	4	5	2	3	4	2	1	4	3	1	3	3	5	4	3	3	4	3	2	4	5	4	5	4	3	3	4	2	3	4
8	5	3	3	3	4	4	2	3	3	4	2	3	4	5	2	2	4	4	3	2	4	5	3	5	4	3	4	4	2	2	3
9	3	3	3	4	2	2	4	2	3	3	4	2	3	3	4	4	2	2	4	3	5	2	3	2	3	4	5	5	4	3	3
10	4	4	3	4	3	4	4	3	3	3	5	3	3	4	4	5	4	4	5	2	4	5	4	4	2	2	5	4	4	4	3
11	4	3	2	4	2	3	4	1	4	3	3	2	5	3	4	4	2	4	3	2	4	4	3	3	4	4	4	4	4	4	4
12	4	4	5	3	4	3	2	2	3	3	1	2	2	4	2	3	2	4	2	2	4	4	3	2	3	4	3	3	1	3	3
13	4	4	4	3	3	4	2	4	4	3	3	4	5	4	4	3	2	4	2	4	3	4	4	4	4	4	4	5	1	5	4
14	3	2	4	3	3	4	1	2	3	3	3	5	5	4	4	2	1	3	4	3	3	3	3	3	3	3	4	3	1	3	5
15	4	3	4	4	3	4	4	5	4	5	3	3	5	4	2	4	4	4	4	2	4	4	4	4	4	4	5	5	4	4	4
16	4	3	4	4	3	4	3	1	4	3	3	4	5	4	5	4	4	4	4	4	4	5	3	3	4	4	5	3	4	4	4
17	4	3	3	4	3	3	3	5	4	3	3	2	4	5	4	4	2	2	3	4	3	3	3	4	3	4	4	4	4	2	4
18	2	3	4	4	2	3	4	1	4	5	4	4	5	5	4	5	3	2	3	5	2	4	2	3	2	4	4	5	2	4	5
19	4	4	3	4	3	4	4	4	3	4	2	4	4	4	5	4	4	3	3	2	4	4	3	2	4	3	5	4	4	3	2
20	2	4	2	3	3	4	2	4	3	5	4	5	5	5	1	4	3	4	4	5	3	4	4	3	3	4	5	5	4	3	4
21	4	4	4	2	3	4	2	3	4	4	3	4	4	3	2	4	3	3	3	4	4	5	3	3	3	4	4	5	2	3	4
22	4	3	3	3	3	2	2	2	3	4	3	4	3	4	1	5	3	3	4	4	3	4	2	1	1	2	2	3	4	3	4
23	4	3	1	4	1	4	1	2	4	4	4	2	4	4	4	3	4	3	2	4	4	3	3	2	2	4	4	4	4	4	4
24	2	3	1	2	1	3	5	3	3	4	4	4	5	4	4	5	2	2	3	5	4	3	2	2	2	3	4	4	4	4	4

4. Alternative Location: Pendik

Score	PARTICIPANTS																													
NO	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1	5	3	5	5	5	4	4	4	4	5	5	5	5	4	5	4	5	3	5	C4	5	5	4	3	4	4	5	5	2	3	5
2	5	3	5	5	4	4	4	4	4	3	5	4	5	5	4	4	4	4	5	4	5	5	4	3	4	4	5	5	2	4	5
3	5	2	5	5	4	5	4	5	4	5	4	4	5	4	4	4	4	4	4	4	5	5	4	5	4	4	5	2	2	4	4
4	4	3	4	5	4	4	4	4	4	5	5	3	3	4	2	4	3	4	3	2	4	4	3	3	2	4	4	4	4	3	3
5	5	4	4	4	4	5	5	2	4	5	5	4	4	4	4	4	3	4	5	4	5	4	4	4	2	4	4	3	4	4	5
6	5	4	4	5	5	4	4	2	5	5	5	4	4	5	4	3	4	4	5	3	4	5	3	4	4	5	4	5	2	5	4
7	5	4	4	5	2	4	3	2	4	3	5	4	4	1	1	3	3	3	4	3	5	5	4	3	1	4	4	4	4	2	4
8	3	4	3	4	2	4	4	1	4	3	4	3	3	2	2	2	2	3	3	4	3	4	3	2	1	4	4	3	2	2	4
9	4	3	4	5	4	3	3	5	3	3	4	4	4	5	5	5	4	3	5	3	5	5	4	4	3	3	4	5	4	5	3
10	5	4	5	5	4	4	4	5	4	2	5	4	4	4	4	4	4	4	5	4	4	4	4	4	5	3	4	4	4	4	4
11	4	3	3	5	5	4	4	5	4	3	4	4	5	3	2	4	3	4	4	4	4	4	4	3	4	4	4	5	4	4	3
12	3	4	3	2	2	4	2	2	4	3	3	3	5	1	2	2	2	4	3	2	2	3	4	2	3	4	3	3	4	2	3
13	4	4	4	2	4	4	3	2	4	4	4	5	5	4	2	3	4	4	3	4	4	3	4	4	4	4	5	5	4	4	4
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15	4	3	4	5	5	4	4	5	3	5	4	4	5	4	4	3	4	4	4	4	4	4	4	4	4	4	5	4	4	4	4
16	4	3	4	5	3	4	4	5	5	4	5	4	5	2	5	3	4	4	4	4	5	5	4	5	4	5	5	4	4	3	4
17	4	3	3	5	3	4	4	5	4	3	4	4	5	4	4	4	4	2	3	4	4	3	3	4	3	4	3	4	4	4	4
18	2	3	1	3	2	2	2	1	3	4	2	2	4	4	1	4	5	2	3	4	2	3	2	2	2	3	4	3	3	2	3
19	2	4	5	3	2	4	4	2	3	3	4	3	3	3	1	3	3	3	2	2	3	3	2	1	2	3	4	4	2	2	3
20	4	4	2	4	2	4	2	5	3	4	5	3	3	5	1	4	4	3	5	3	3	3	4	3	1	4	5	4	4	3	4
21	3	4	4	4	3	4	3	3	4	3	4	4	3	3	2	4	3	3	3	4	4	4	3	2	1	4	5	5	2	2	4
22	4	4	5	5	4	4	4	2	4	5	5	4	5	4	1	5	3	3	3	4	4	4	4	4	1	5	5	5	4	3	4
23	5	4	4	5	4	5	4	4	3	4	4	4	3	4	1	4	5	2	4	4	3	4	4	3	2	5	5	5	4	5	4
24	5	4	3	5	4	4	3	5	3	4	5	5	4	4	4	4	5	4	5	5	4	4	4	4	4	5	5	5	3	5	4

C. SPSS REPORTS & SURVEY 2 EVALUATION

1. Descriptive Statistics

- **Kasimpasa**

	N	Range	Minimum	Maximum	Mean		Std. Deviation	Variance
CRITERIA	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic
C01	31	4.00	1.00	5.00	3.4839	.1847	1.0286	1.058
C02	31	3.00	2.00	5.00	4.1613	.1145	.6375	.406
C03	31	3.00	2.00	5.00	4.1935	.1423	.7924	.628
C04	31	3.00	2.00	5.00	3.8065	.1497	.8334	.695
C05	31	3.00	2.00	5.00	3.8710	.1204	.6704	.449
C06	31	3.00	2.00	5.00	3.4516	.1786	.9946	.989
C07	31	4.00	1.00	5.00	3.4839	.2067	1.1510	1.325
C08	31	3.00	2.00	5.00	3.7419	.1966	1.0945	1.198
C09	31	4.00	1.00	5.00	3.1290	.1719	.9571	.916
C10	31	4.00	1.00	5.00	3.6774	.1565	.8713	.759
C11	31	4.00	1.00	5.00	3.0323	.1703	.9481	.899
C12	31	4.00	1.00	5.00	4.0000	.1855	1.0328	1.067
C13	31	2.00	3.00	5.00	4.1290	8.971E-02	.4995	.249
C14	31	4.00	1.00	5.00	2.9032	.2241	1.2478	1.557
C15	31	3.00	2.00	5.00	3.5806	.1782	.9924	.985
C16	31	2.00	3.00	5.00	4.0645	.1130	.6290	.396
C17	31	4.00	1.00	5.00	3.4839	.1598	.8896	.791
C18	31	3.00	1.00	4.00	2.4516	.1455	.8099	.656
C19	31	4.00	1.00	5.00	2.2581	.1910	1.0636	1.131
C20	31	3.00	2.00	5.00	3.4516	.1903	1.0595	1.123
C21	31	4.00	1.00	5.00	3.6452	.1576	.8774	.770
C22	31	4.00	1.00	5.00	3.6452	.2050	1.1416	1.303
C23	31	3.00	1.00	4.00	2.2258	.1587	.8835	.781
C24	31	3.00	1.00	4.00	2.0323	.1703	.9481	.899

- **Sariyer**

	N	Range	Minimum	Maximum	Mean		Std. Deviation	Variance
CRITERIA	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic
C01	31	4.00	1.00	5.00	3.1290	.1655	.9217	.849
C02	31	3.00	2.00	5.00	3.3871	.1585	.8823	.778
C03	31	3.00	2.00	5.00	3.5484	.1596	.8884	.789
C04	31	3.00	2.00	5.00	3.6774	.1632	.9087	.826
C05	31	3.00	2.00	5.00	3.4516	.1596	.8884	.789
C06	31	3.00	2.00	5.00	2.9355	.1534	.8538	.729
C07	30	2.00	3.00	5.00	4.1333	.1244	.6814	.464
C08	31	3.00	2.00	5.00	4.3548	.1433	.7978	.637
C09	31	4.00	1.00	5.00	2.4194	.1522	.8475	.718
C10	31	2.00	2.00	4.00	3.3548	.1187	.6607	.437
C11	31	3.00	1.00	4.00	3.1613	.1613	.8980	.806
C12	31	4.00	1.00	5.00	3.7742	.1587	.8835	.781
C13	31	3.00	2.00	5.00	3.9032	.1169	.6509	.424
C14	31	4.00	1.00	5.00	3.3871	.1715	.9549	.912
C15	31	3.00	2.00	5.00	3.7742	.1369	.7620	.581
C16	31	3.00	2.00	5.00	3.8710	.1290	.7184	.516
C17	31	3.00	2.00	5.00	3.2903	.1406	.7829	.613
C18	31	4.00	1.00	5.00	3.2903	.2328	1.2960	1.680
C19	31	3.00	2.00	5.00	3.9032	.1258	.7002	.490
C20	31	3.00	2.00	5.00	3.7419	.1536	.8551	.731
C21	31	3.00	2.00	5.00	3.9355	.1130	.6290	.396
C22	31	3.00	1.00	4.00	3.0968	.1695	.9436	.890
C23	31	3.00	1.00	4.00	2.5806	.1842	1.0255	1.052
C24	31	4.00	1.00	5.00	2.5161	.2015	1.1216	1.258

- **Beykoz**

	N	Range	Minimum	Maximum	Mean		Std. Deviation	Variance
CRITERIA	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic
C01	31	4.00	1.00	5.00	3.0323	.1825	1.0160	1.032
C02	31	3.00	2.00	5.00	3.4839	.1664	.9263	.858
C03	31	3.00	2.00	5.00	3.5161	.1529	.8513	.725
C04	31	4.00	1.00	5.00	3.3871	.1651	.9193	.845
C05	31	4.00	1.00	5.00	3.4194	.1522	.8475	.718
C06	31	3.00	2.00	5.00	3.1935	.1497	.8334	.695
C07	31	4.00	1.00	5.00	3.3548	.1943	1.0816	1.170
C08	31	3.00	2.00	5.00	3.3548	.1769	.9848	.970
C09	31	3.00	2.00	5.00	3.1935	.1699	.9458	.895
C10	31	3.00	2.00	5.00	3.7097	.1552	.8638	.746
C11	31	4.00	1.00	5.00	3.3548	.1643	.9146	.837
C12	31	4.00	1.00	5.00	2.9032	.1757	.9783	.957
C13	31	4.00	1.00	5.00	3.6129	.1651	.9193	.845
C14	31	4.00	1.00	5.00	3.0968	.1875	1.0442	1.090
C15	31	3.00	2.00	5.00	3.9032	.1340	.7463	.557
C16	31	4.00	1.00	5.00	3.7742	.1445	.8046	.647
C17	31	3.00	2.00	5.00	3.4194	.1450	.8072	.652
C18	31	4.00	1.00	5.00	3.5161	.2119	1.1796	1.391
C19	31	3.00	2.00	5.00	3.5484	.1455	.8099	.656
C20	31	4.00	1.00	5.00	3.6774	.1877	1.0452	1.092
C21	31	3.00	2.00	5.00	3.4516	.1455	.8099	.656
C22	31	4.00	1.00	5.00	2.9677	.1825	1.0160	1.032
C23	31	3.00	1.00	4.00	3.2258	.1896	1.0555	1.114
C24	31	4.00	1.00	5.00	3.2581	.2072	1.1538	1.331

- **Pendik**

	N	Range	Minimum	Maximum	Mean		Std. Deviation	Variance
CRITERIA	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic
C01	31	3.00	2.00	5.00	4.3333	.1541	.8442	.713
C02	31	3.00	2.00	5.00	4.2258	.1369	.7620	.581
C03	31	3.00	2.00	5.00	4.1613	.1545	.8601	.740
C04	31	3.00	2.00	5.00	3.6129	.1443	.8032	.645
C05	31	3.00	2.00	5.00	4.0645	.1386	.7718	.596
C06	31	3.00	2.00	5.00	4.1613	.1545	.8601	.740
C07	31	4.00	1.00	5.00	3.4516	.2117	1.1787	1.389
C08	31	3.00	1.00	4.00	2.9677	.1703	.9481	.899
C09	31	2.00	3.00	5.00	4.0000	.1466	.8165	.667
C10	31	3.00	2.00	5.00	4.1290	.1111	.6187	.383
C11	31	3.00	2.00	5.00	3.8710	.1290	.7184	.516
C12	31	4.00	1.00	5.00	2.8710	.1655	.9217	.849
C13	31	3.00	2.00	5.00	3.8065	.1423	.7924	.628
C14	31	2.00	3.00	5.00	4.0968	.1258	.7002	.490
C15	31	2.00	3.00	5.00	4.0968	9.677E-02	.5388	.290
C16	31	3.00	2.00	5.00	4.1613	.1399	.7788	.606
C17	31	3.00	2.00	5.00	3.7419	.1224	.6816	.465
C18	31	4.00	1.00	5.00	2.6774	.1819	1.0128	1.026
C19	31	4.00	1.00	5.00	2.8387	.1678	.9344	.873
C20	31	4.00	1.00	5.00	3.4839	.1960	1.0915	1.191
C21	31	4.00	1.00	5.00	3.3548	.1643	.9146	.837
C22	31	4.00	1.00	5.00	3.9032	.1932	1.0756	1.157
C23	31	4.00	1.00	5.00	3.9032	.1757	.9783	.957
C24	31	2.00	3.00	5.00	4.2581	.1224	.6816	.465

2. Reliability Analysis: Scale (Parallel)

a. Report for Kasimpasa

- **Intraclass Correlation Coefficient**

Two-Way Mixed Effect Model (Consistency Definition):

People Effect Random, Measure Effect Fixed

Average Measure Intraclass Correlation = .8223

95.00% C.I.: Lower = .7179 Upper = .9013

- **Parameter Estimates**

Estimated common variance = .8763

Error variance = .7346

True variance = .1417

Estimated reliability of scale = **.8223**

Unbiased estimate of reliability = **.8342**

b. Report for Sariyer

- **Intraclass Correlation Coefficient**

Two-Way Mixed Effect Model (Consistency Definition):

People Effect Random, Measure Effect Fixed

Average Measure Intraclass Correlation = .7730

95.00% C.I.: Lower = .6396 Upper = .8739

- **Parameter Estimates**

Estimated common variance = .7554

Error variance = .6616

True variance = .0939

Estimated reliability of scale = **.7730**

Unbiased estimate of reliability = **.7881**

c. Report for Beykoz

- **Intraclass Correlation Coefficient**

Two-Way Mixed Effect Model (Consistency Definition):

People Effect Random, Measure Effect Fixed

Average Measure Intraclass Correlation = .8043

95.00% C.I.: Lower = .6893 Upper = .8913

- **Parameter Estimates**

Estimated common variance = .8963

Error variance = .7653

True variance = .1310

Estimated reliability of scale = **.8043**

Unbiased estimate of reliability = **.8173**

d. Report for Pendik

- **Intraclass Correlation Coefficient**

Two-Way Mixed Effect Model (Consistency Definition):

People Effect Random, Measure Effect Fixed

Average Measure Intraclass Correlation = .8216

95.00% C.I.: Lower = .7168 Upper = .9009

- **Parameter Estimates**

Estimated common variance = .7366

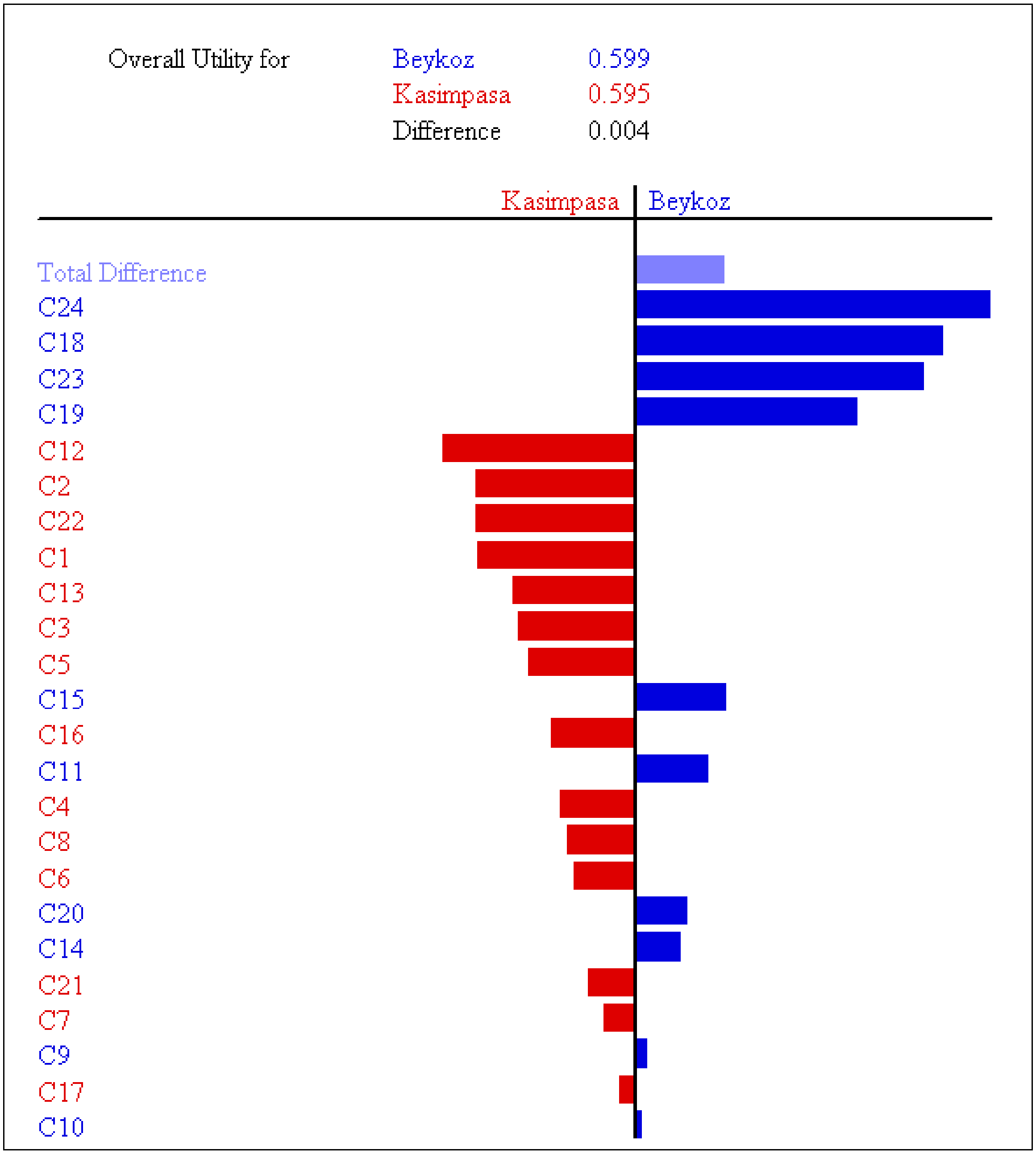
Error variance = .6180

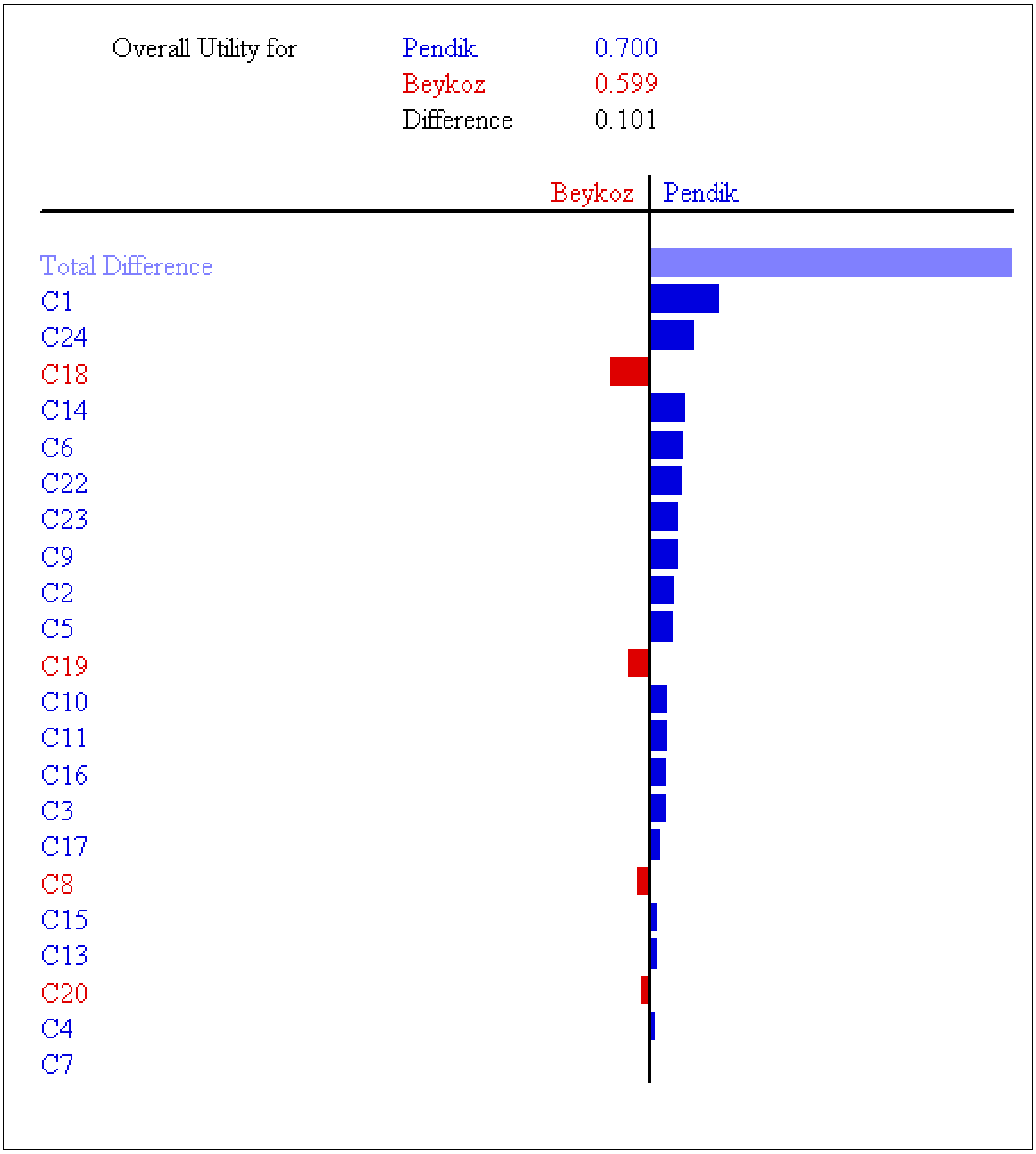
True variance = .1186

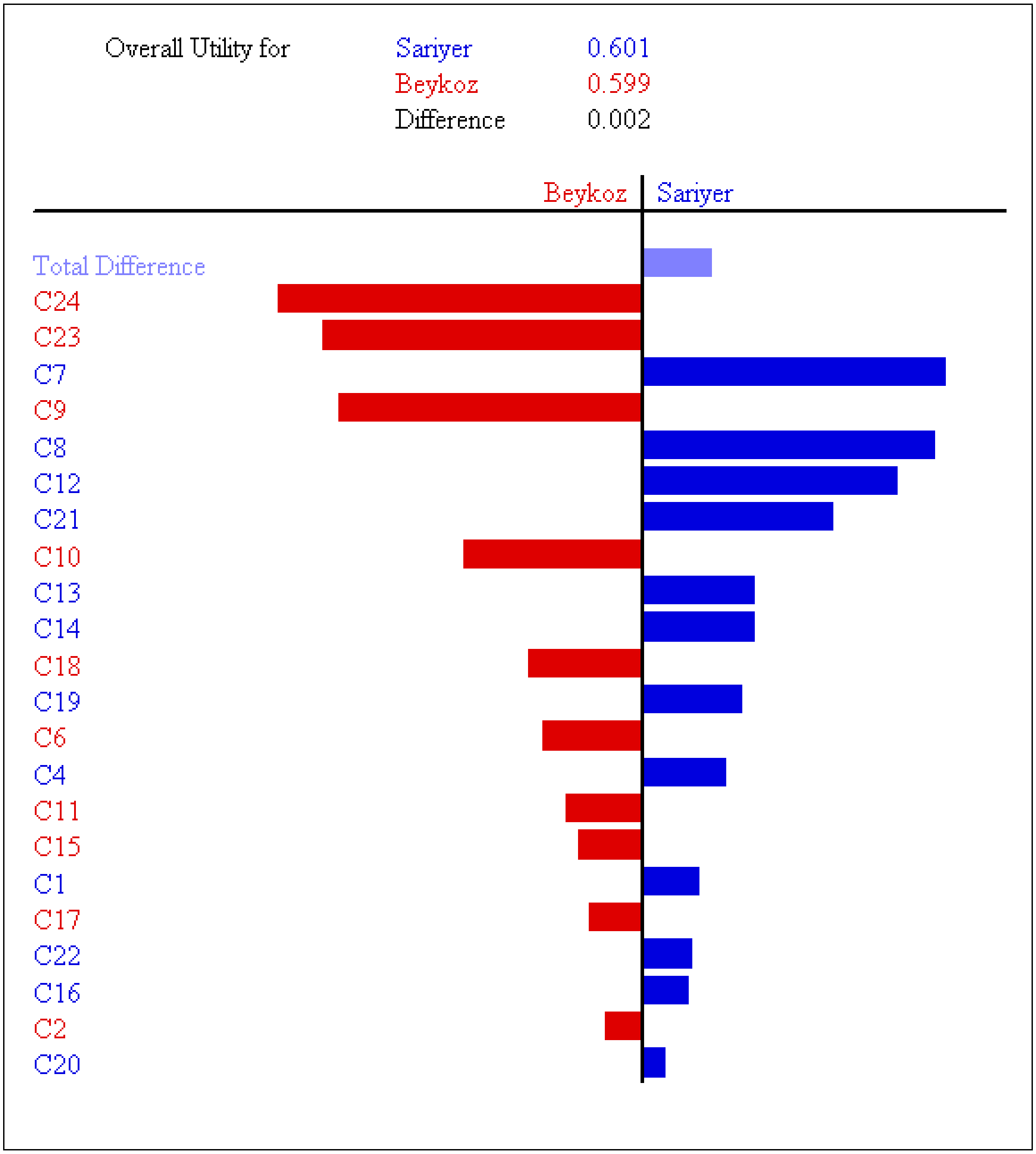
Estimated reliability of scale = **.8216**

Unbiased estimate of reliability = **.8335**

APPENDIX E - LDW ALTERNATIVE COMPARISON GRAPHS




Overall Utility for
Pendik 0.700
Beykoz 0.599
Difference 0.101
Beykoz
Pendik
Total Difference
C1
C24
C18
C14
C6
C22
C23
C9
C2
C5
C19
C10
C11
C16
C3
C17
C8
C15
C13
C20
C4
C7


Overall Utility for
Sariyer 0.601
Beykoz 0.599
Difference 0.002
Beykoz
Sariyer
Total Difference
C24
C23
C7
C9
C8
C12
C21
C10
C13
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C19
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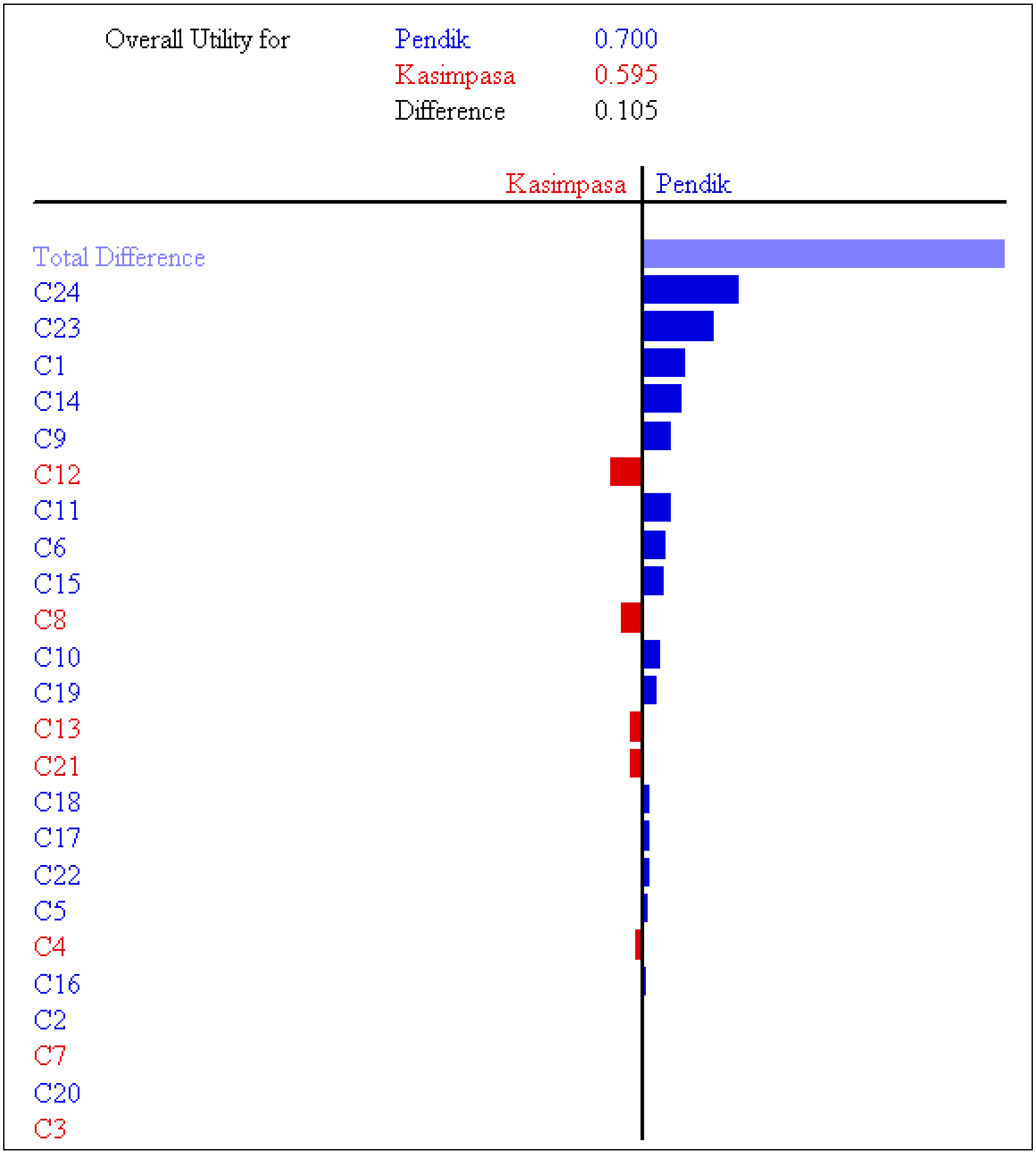
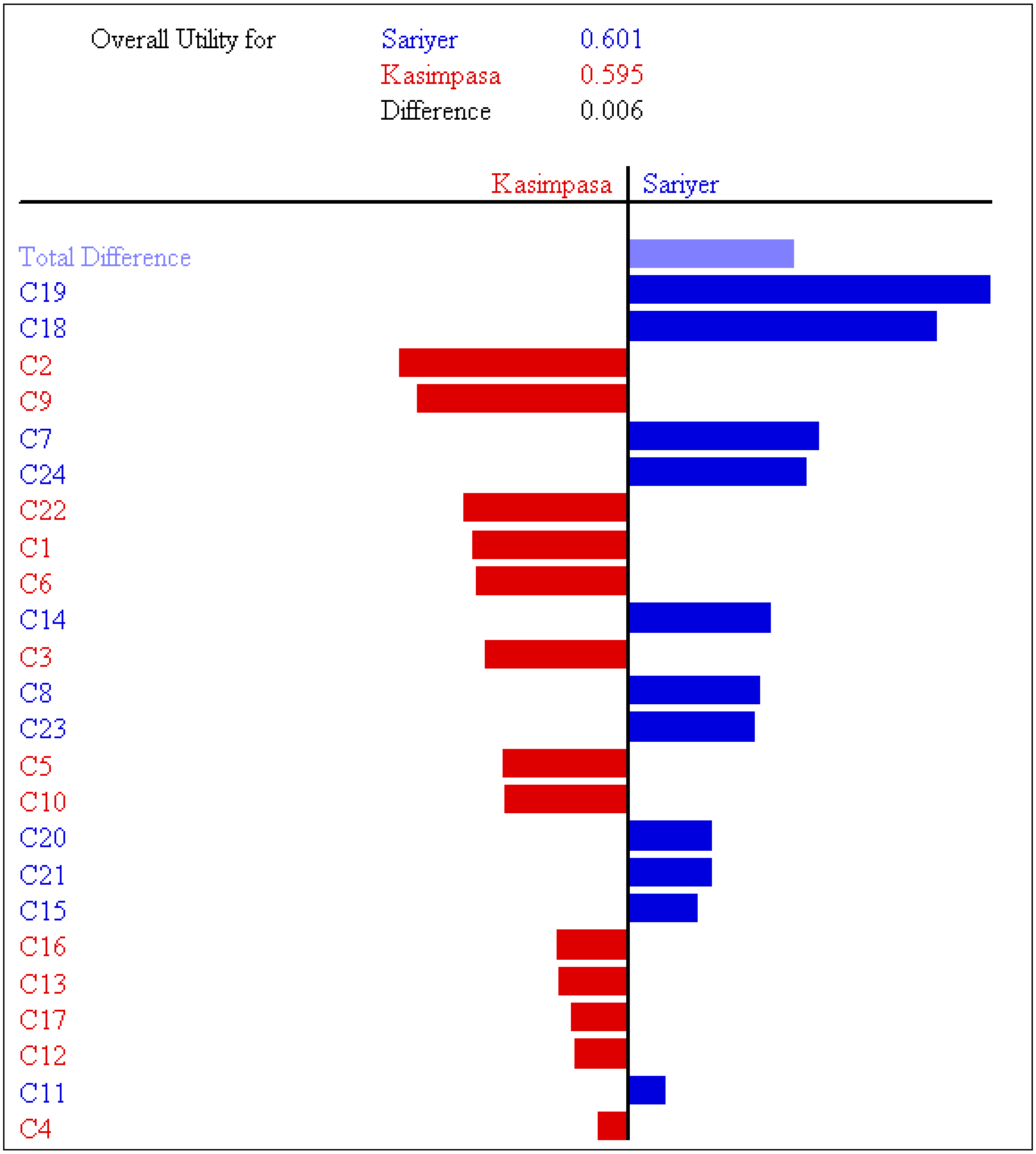
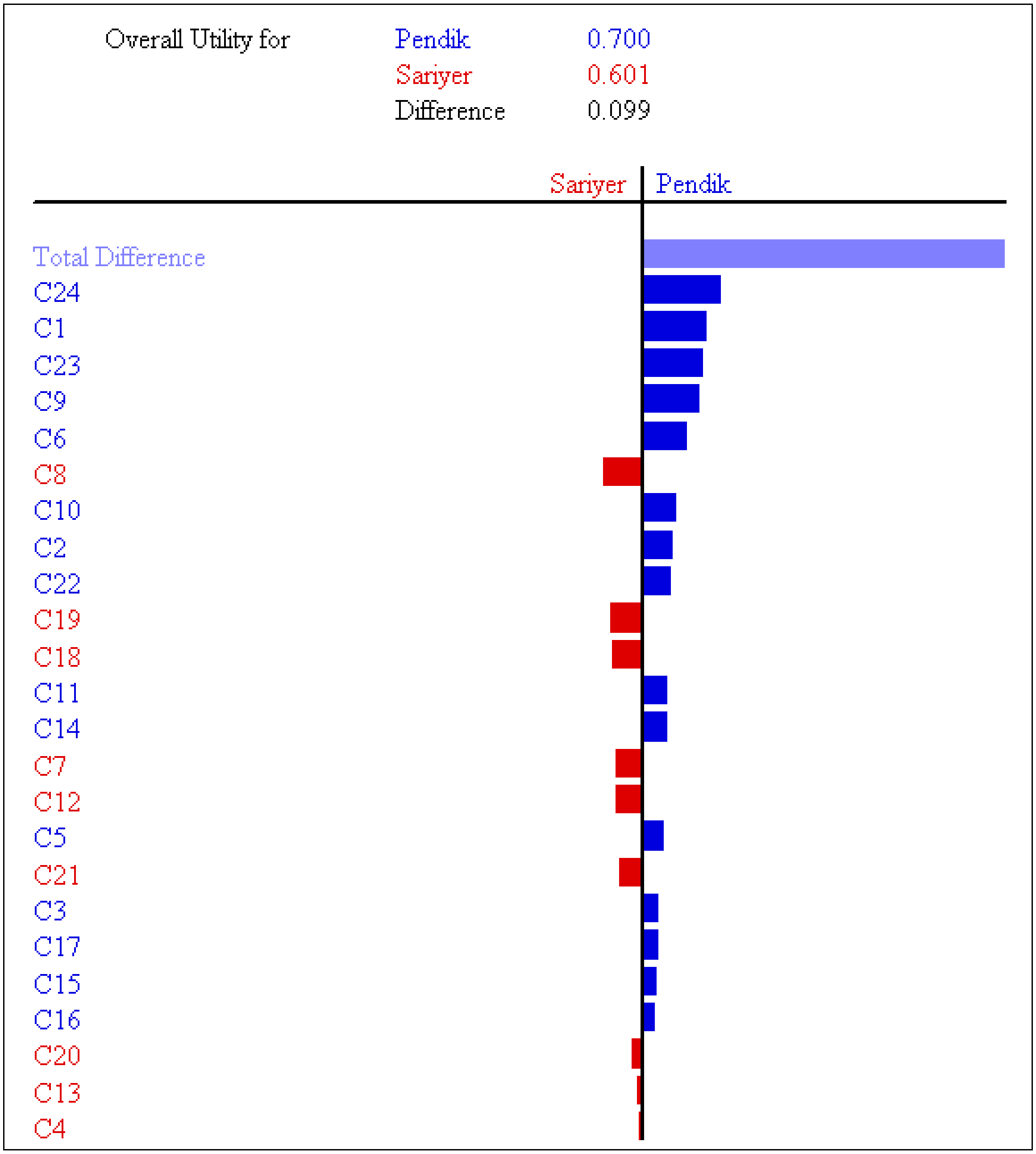
C11
C15
C1
C17
C22
C16
C2
C20


Overall Utility for
Pendik 0.700
Kasimpasa 0.595
Difference 0.105
Kasimpasa
Pendik
Total Difference
C24
C23
C1
C14
C9
C12
C11
C6
C15
C8
C10
C19
C13
C21
C18
C17
C22
C5
C4
C16
C2
C7
C20
C3


Overall Utility for
Sariyer 0.601
Kasimpasa 0.595
Difference 0.006
Kasimpasa
Sariyer
Total Difference
C19
C18
C2
C9
C7
C24
C22
C1
C6
C14
C3
C8
C23
C5
C10
C20
C21
C15
C16
C13
C17
C12
C11
C4


Overall Utility for
Pendik 0.700
Sariyer 0.601
Difference 0.099
Sariyer
Pendik
Total Difference
C24
C1
C23
C9
C6
C8
C10
C2
C22
C19
C18
C11
C14
C7
C12
C5
C21
C3
C17
C15
C16
C20
C13
C4

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